POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

VOL. XXVIII CHICAGO, MARCH 15, 1924 No. 6

Salt Manufacturer Installs 3625 Kw.

NEW POWER PLANT OF RUGGLES & RADEMAKER READY TO PICK UP THE LOAD AS PLANT EXTENSIONS ARE COMPLETED

EXTENDING ACROSS the State of Michigan from Ludington and Manistee on the Lake Michigan shore to Saginaw and Detroit in the eastern part of the state is an immense salt deposit. Ruggles and Rademaker, manufacturers of salt, have chosen Manistee as the location for their greatly enlarged development of this salt deposit. One of the first steps in this project was the construction of a modern power plant which must furnish electricity, high and low pressure steam and compressed air. This plant is now completed and is daily taking on more load as the various new plant extensions are put into operation.

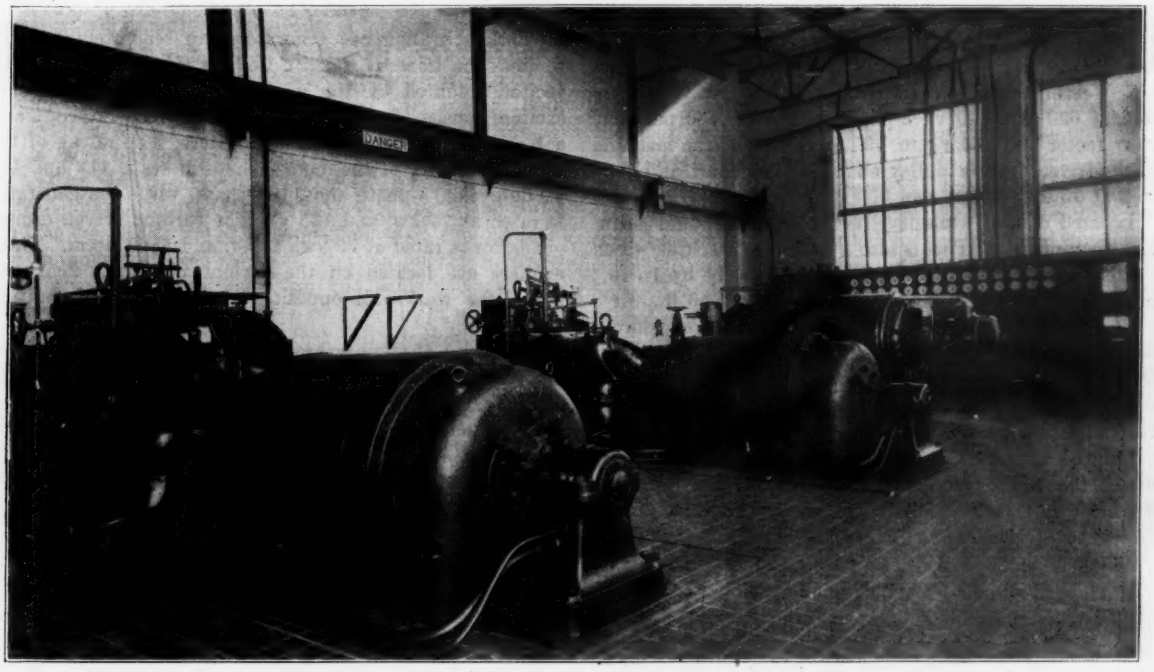


FIG. 1. THREE GENERATING UNITS HAVE BEEN INSTALLED, TWO OF THE BLEEDER AND ONE OF THE NON-CONDENSING TYPE

As one enters this plant, it is noticed that the main generating room is divided so that there are two floor levels. The lower level, consisting of the north half of the room is just slightly above the yard grade, in fact a standard gage switch track extends into the building at this level. The overhead electric crane covers both levels of this room. This makes a convenient method of transferring heavy pieces of machinery from railroad cars to the operating floor. At the present time, pending the construction of a locomotive shed, this track is used as a stall for the fireless steam locomotive which is used for yard switching.

This locomotive is of interest because it consists of only a cylindrical shell and the necessary engine and drive equipment. No fire box or tender is provided for the reason that the heavily insulated shell is charged with water at the temperature and pressure carried in the power plant boilers. The heat or energy thus stored is sufficient to operate this fireless locomotive for 5 or 6 hr. of comparatively heavy switching duty. At the expiration of that time the locomotive must return to the power plant and be given a new charge.

Salt from the deposit is obtained by pumping brine from deep wells. This is accomplished by means of

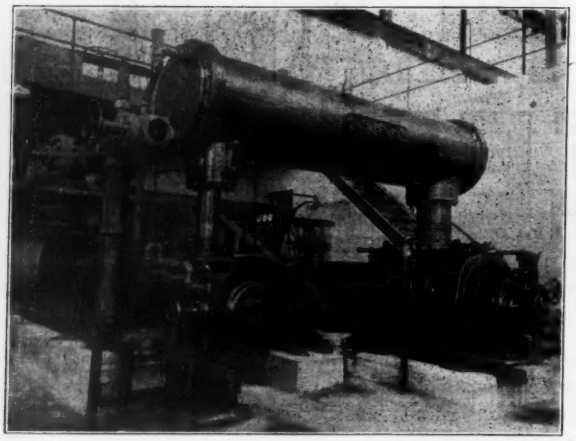


FIG. 2. ONE AIR COMPRESSOR IS DRIVEN BY A SYNCHRONOUS MOTOR

hydraulic air lifts which operate at a pressure of 375 lb. per sq. in. Air for these lifts is furnished at present by two air compressors which are located on the lower level of the main generating room. One of these compressors is a two-stage machine, the size of which is 23 by 10½ by 24 in. This compressor was built by the Worthington Pump & Machinery Corp. and it is driven direct by means of a Westinghouse synchronous motor. This motor is rated at 600 hp., 440 v., 3-phase, 60 cycles, 100 per cent power factor and 164 r.p.m. The exciter for the machine is belt driven from a pulley on the motor shaft and it is rated at 15 kw., 120 v. and 900 r.p.m.

Located on this same level is an Ingersoll-Rand steam driven compressor. This is also a two-stage machine which is rated as follows—right-hand side; steam 14 by 16 in.; air 17 by 16 in. Left-hand side, steam 14 by 16 in., air 8 by 16 in. This machine is equipped with a McCord forced feed lubricator. A foundation is in place for another steam driven compressor and there still remains space for several additional units which may be required as more brine wells are pumped.

On the upper level of the main generating room are located the turbo-generators, exciter units and the main switchboard. Two of the turbo-generators are of the Westinghouse bleeder type. They are rated at 1875 kv.a., 480 v., 3-phase, 60 cycles and 3600 r.p.m. The guarantee on these machines was as follows:

Turbine load, kw.	Steam bled in lb. per hr.	Steam required in lb. per hr.
750	31,000	32,200
1500	52,000	53,200

The third unit was made by the General Electric Co.; it is the only unit which was taken from the old plant and reset in the new power plant. It is a non-condensing unit of which the rating is 625 kw. at 80 per cent power factor, 480 v., 3-phase, 60 cycles and 3600 r.p.m. Ample space has been left in which to locate a fourth turbine unit.

Each turbine unit is equipped with a Griscom-Russell multiwhirl oil cooler, and at present there is being installed a Bowser bypass system for purifying the oil from those units.

Extending across this room at the extreme north end is the main switchboard which is also a Westinghouse unit. Its arrangement is simple and neat and the visitor will immediately be impressed by the good workmanlike manner in which it has been erected. There is ample room back of the board to carry on whatever maintenance work may be necessary and large window openings provided with steel sash afford an abundance of daylight back of the board.

Both Westinghouse generators are separately excited, whereas the General Electric Co. unit is provided with an exciter mounted on the generator shaft. The separate exciters consist of a Westinghouse motor-generator set and a Westinghouse turbine driven exciter. The rating of the induction motor of the motor-generator set is 112 hp., 440 v., 60 cycles, 3-phase and 1160 r.p.m. while the generator is rated at 75 kw. and 125 v. The turbine driven exciter generator is rated at 75 kw., 125 v. and 1800 r.p.m. These exciters are located on the turbine operating floor and along the west wall opposite the two south generating units.

Capacity of the overhead electric traveling crane is 20 T., this crane was manufactured by Pawling & Harnischfiger Co., and as previously outlined its travel covers the main generating and exciter units as well as the compressors. The roof over the generating room is of the so termed flat type, consisting of steel trusses and purlins which support concrete tile over which is laid composition roofing.

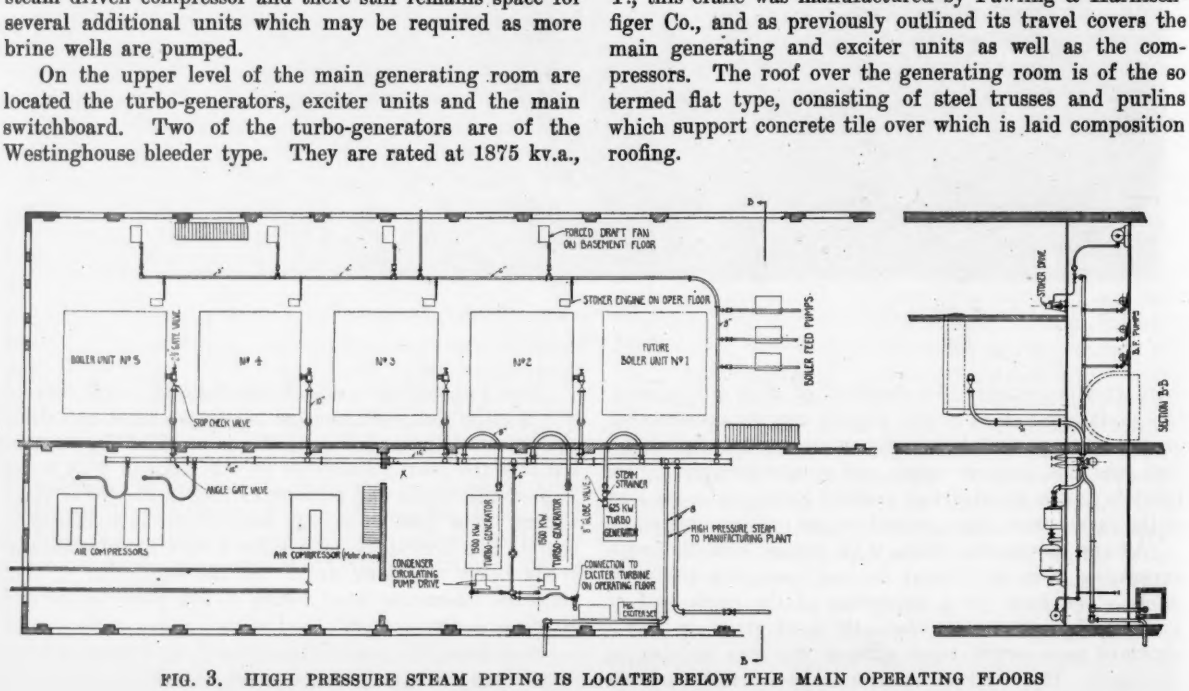


FIG. 3. HIGH PRESSURE STEAM PIPING IS LOCATED BELOW THE MAIN OPERATING FLOORS

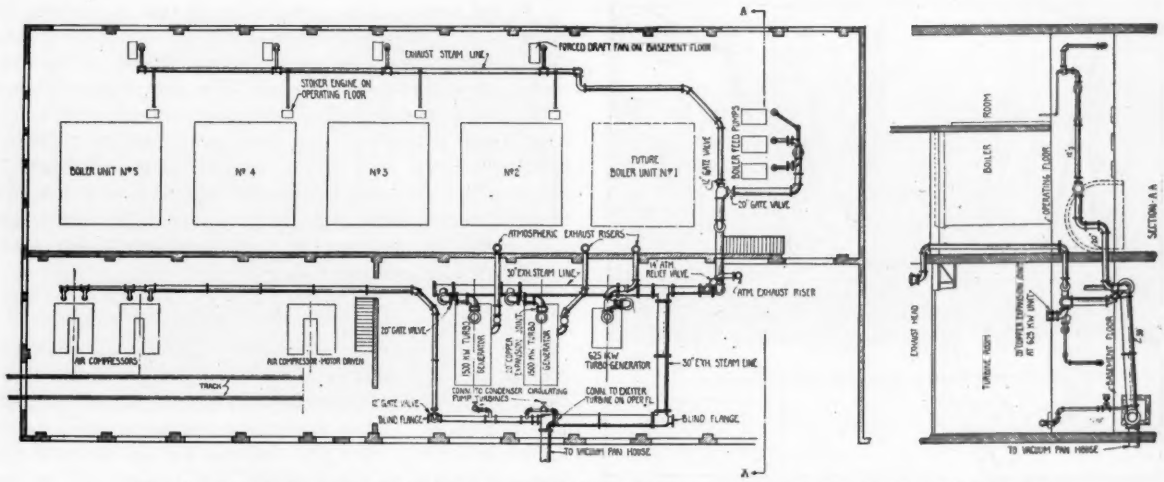


FIG. 4. LOW PRESSURE STEAM LEAVES THE POWER HOUSE BASEMENT THROUGH A 30-IN. LINE

On the lower level or compressor end of this room the floor is of concrete; on the upper level or generator end the floor is of end tile. The walls are of brick laid up with a smooth surface. These walls have been given several coats of white paint which gives a pleasing appearance when contrasted with the structural work which has been painted dark green. Ventilated steel sash covers a large portion of the three outside walls of this room. Wall brackets have been mounted so that all necessary instruments for turbine operation can be brought to one centralized location.

Advantages derived from the generating room being built on two levels are at once evident when the condensing equipment is taken into consideration for this arrangement places this equipment on the same level as the compressors, thus the condenser room is not in a basement but is above the yard level so that full advantage may be taken of daylight.

As previously stated, the General Electric unit is non-condensing, all exhaust steam being turned directly into the low pressure mains from which the process work is supplied. Each of the Westinghouse bleeder type turbines is equipped with a Westinghouse surface condenser each of which contains 2400 sq. ft. of tube surface. These condensers are guaranteed to maintain a vacuum of 28.5 in. of mercury when each is condensing 21,900 lb. of steam per hr. and supplied with 1,200,000 lb. of water per hour at a temperature of 81 deg. F. Each condenser is equipped with a condensate removal pump and a circulating pump which are mounted on one shaft and driven by means of a Westinghouse non-condensing turbine. Air is removed by means of an hydraulic air pump.

Boilers Are Set Singly

From the turbine operating floor one can go directly into the boiler room, these two main operating floors being at the same level. The boilers are set singly and with their rear setting walls spaced about 8 ft. from the inner or partition wall which separates the boiler and turbine rooms. At present four boilers are in place and space has been left for the placing of a fifth unit.

These boilers are of the Edge Moor horizontal drum type, each of which is rated at 1043 hp. They are designed for 200 lb. working pressure although the pressure maintained at present is 180 lb. gage. Each boiler is set with the rear header 12 ft. 3½ in. above the floor and the baffles are arranged to give four passes across the tube nest. In the fourth or last pass the gas is directed downward. The gas at this point is carried through the operating floor to a breeching located just under this floor. In this way the location of the breeching in the rear aisle and below the rear header has been avoided. This rear gas passage is made by constructing a fire brick wall which extends from the floor up to the rear baffle.

Foster superheaters have been installed, which add 100 deg. F. to the temperature of the steam. The stokers in this plant are of the nine retort Westinghouse underfeed type, each stoker being driven by an individual direct connected Westinghouse steam engine. The stoker dump plates are operated by hand. Mounted on each boiler frame, directly above the stoker engine, is a Bailey meter which indicates the draft in the uptake and in the firebox and also indicates the wind box pressure. On the same board with this indicator is mounted a Bailey meter which records the air flow, the steam flow and the flue gas temperature.

Accessories with which each boiler is equipped are a 10-in. Lunkenheimer non-return valve, Homestead plug and Everlasting blowoff valves, Diamond Valv-in-head soot blowers, four 4-in. Consolidated safety valves on the

FIG. 5. OPERATING CREW IN CHARGE OF THE BOILER ROOM

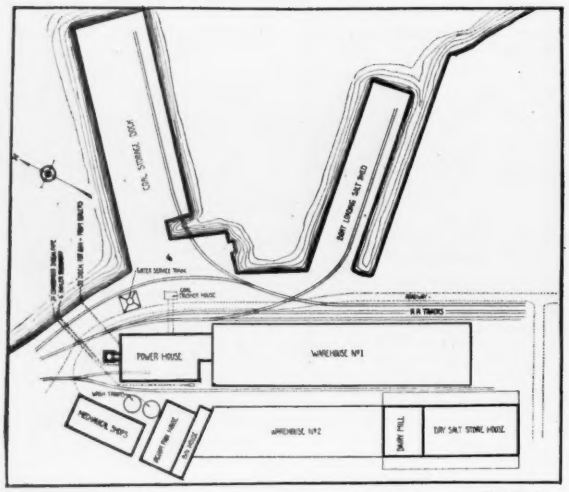


FIG. 6. COAL DOCK HAS A STORAGE CAPACITY OF 50,000 T.

boiler and one 3-in. safety valve of the same make on the superheater and a Copes feed water regulator. These regulators are bypassed, the bypass valve being operated from the main floor by means of chains. Each boiler is blown down twice during a 12-hr. shift. Waste gas from the boilers is carried through a steel breeching, concrete lined, to a radial brick stack located at the north end of the building. This stack is unlined and is 252 ft. high and 16 ft. in diameter at the top.

Four Buffalo fans, direct connected to Westinghouse non-condensing turbines furnish the air blast for the stokers. These fans are on the floor below the main boiler operating floor. A steel air duct leads from each fan to a main duct which runs the full length of the boiler room. Dampers have been provided so that any combination of fans may be used to supply air for combustion. Stokers, boiler dampers and blast fans are all manually controlled.

Transport of fuel to this plant is greatly facilitated due to the location on an inland lake which is connected by a deep waterway to Lake Michigan. Coal may be brought either by rail or by lake steamers. A coal storage dock has been constructed which is provided with a track upon which a locomotive crane will operate for the purpose of unloading and reclaiming coal. It is estimated that approximately 50,000 T. of coal can be stored on this dock. In the near future a drag line reclaimer will be installed which will convey coal from the dock to the hopper which is over the crusher.

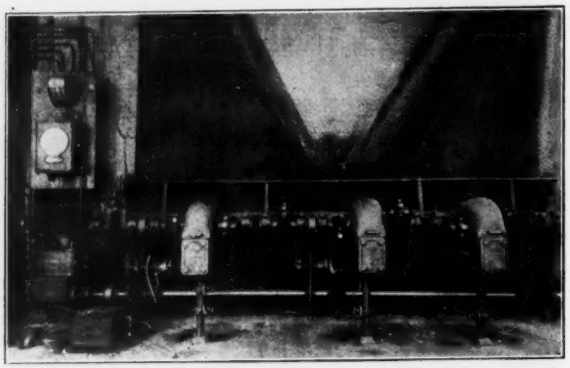


FIG. 7. EACH STOKER IS SEPARATELY DRIVEN BY A STEAM ENGINE

At the present time practically all coal is brought in by rail and is unloaded either on the storage piles or into the crusher hopper by an Industrial Works locomotive crane. A feeder takes the coal from the crusher hopper and delivers it to a Stephens-Adamson single roll crusher, from which a drag conveyor delivers the coal to a Jeffrey bucket conveyor. The bucket conveyor passes over the full length of an overhead coal bunker which is located above the boiler room firing aisle. By means of a movable tripper this conveyor can be made to unload at any point along the length of the coal bunker.

Conveyor Controls Are Interconnected

All conveyors are operated by General Electric Co. motors and the controls of these motors are arranged so that the stalling or stopping of one conveyor will stop all motors back of it, thus preventing coal being piled up on a dead conveyor. Stop push buttons for the conveyor system are located at the overhead coal bunker and on the operating floor.

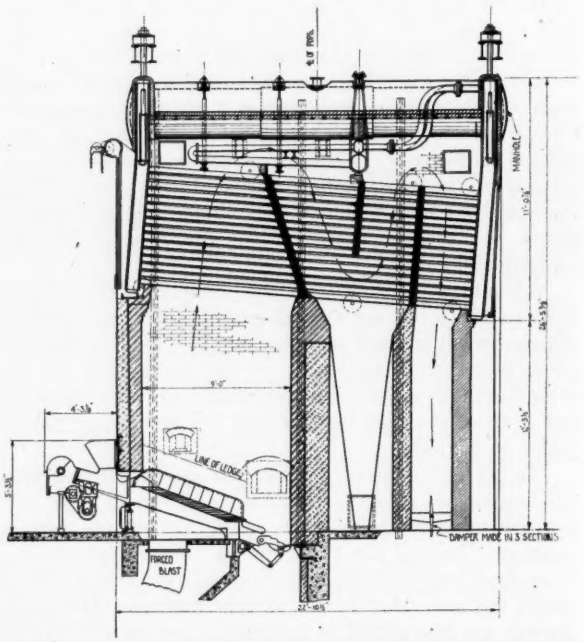


FIG. 8. BAFFLE ARRANGEMENT PROVIDES FOR FOUR GAS PASSAGES

When the coal handling system was first installed, two down spouts were provided from the overhead bunker to each stoker, each down spout being equipped with a separate coal weighing device. This scheme did not prove entirely practical and it is planned to remove the scales and down spouts and replace them with several coal weighing larries. The proposed scheme will be more flexible than the present arrangement because it will then be possible to take coal from any section of the bunker and deliver it to any stoker hopper. The overhead coal bunker which has a capacity of 900 T., is made of steel and is of the parabolic or slung type. It is unlined at present but will be lined with concrete in the near future.

What would ordinarily be termed the boiler room basement in most plants is actually the first floor because the floor below the stoker level is but slightly above the yard grade and is on the same level as the floor in the com-

FIG. 9. BOILER FEED PUMPS CONSIST OF THREE TURBINE DRIVEN UNITS

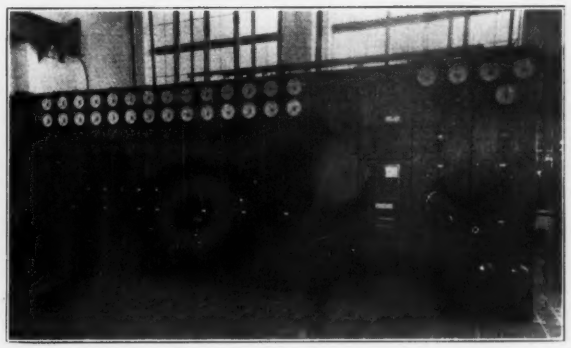


FIG. 11. GENERAL VIEW OF THE MAIN SWITCHBOARD

pressor portion of the main generating room. This is a decided advantage because ample light and ventilation are provided for the ash handlers.

Ash may be disposed of in two ways. The single dump plates provided with the stokers drop the ash and clinker into concrete hoppers. These hoppers are constructed with a flat bottom, the level of which is about 2 ft. above the floor. The ash gates are of the vertical, hinged type and were made by the Conveyors Corporation of America. The ash is thoroughly quenched in the hopper and must then be shoveled or raked out of the hopper.

Running parallel with the boiler fronts is an ash sluiceway, water for which is supplied by service pumps. The operator may dispose of the ash by sluicing or by the Jeffrey bucket conveyor. The former discharges into the lake where the ash may be reclaimed by the locomotive crane. When the conveyor is used, the ash is unloaded into an overhead bunker located at one end of the boiler room. The ash may be spouted from this bunker to railroad cars or to trucks.

All water for this plant is taken from the inland lake where a screen house has been built over the plant intake. The screens are of the stationary type, that is they are non-rotative; they may be removed, however, for cleaning or maintenance by means of a chain hoist. A tunnel leads from the screen house to a settling well at the power plant. The tunnel then extends on into the plant to the service pumps which draw water directly from the tunnel and discharge into a 30,000 gal. overhead tank the top of which is 155 ft. above the ground level. Water for the condensers is taken directly from the settling well and after having served its purpose is discharged into another well which is drained to the lake by a 20-in. cast iron pipe.

Two Roturbo pumps, manufactured by the Manistee Iron Works, are provided as service or house pumps. Each is rated 600 gal. per min. against a 175-ft. head. Each pump is driven by a General Electric induction motor which is rated at 40 hp., 440 v., 3-phase, 60 cycles and 1750 r.p.m. One Henry R. Worthington, duplex fire pump is being installed at the present time.

Feed water consists of condensate from the condensers, returns from the salt vacuum pans, high pressure drips and makeup. Low pressure drips are allowed to run to waste. That condensate which is returned from outside of the power plant ranges in temperature from 120 to 160 deg. F. High pressure drips are returned to the feed water heater by means of Detroit traps which are manufactured by the American Blower Co. Make up water is taken directly from the overhead service tank and is controlled by a float valve in the heater.

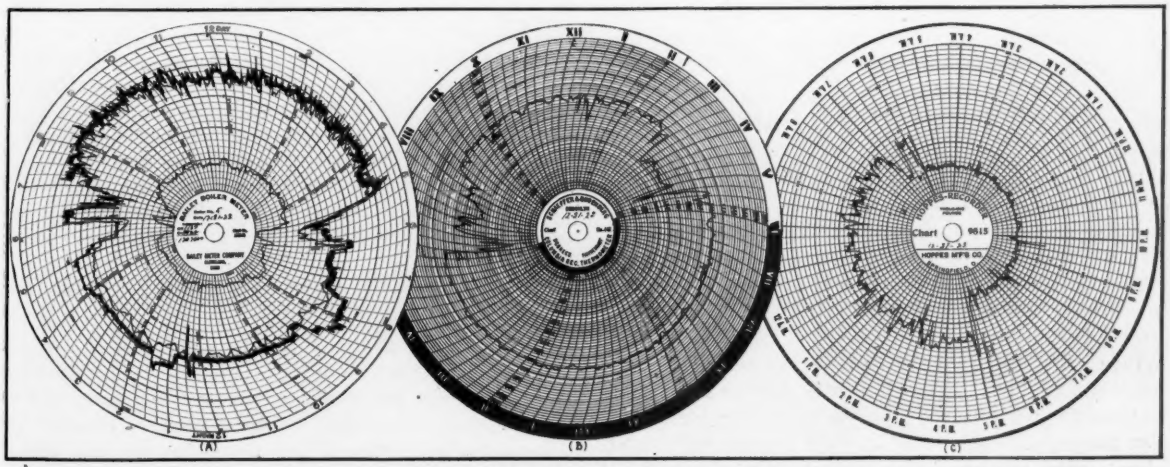


FIG. 10. OPERATING CHARTS SHOW THAT THE PLANT IS OPERATING UNDER FULL LOAD ON THE DAY TURN ONLY

Chart A was taken from a Bailey boiler meter. The outer curves show steam and air flow and the inner curve shows the flue gas temperature.

Chart B shows the temperature of the feed water. When the salt evaporating pans are operating it is necessary to use some high pressure steam to bring the feed water temperature up to 200 deg. F.

Chart C is a record of the water fed to the boilers. This chart shows that the day load is approximately 2½ times the night load.

Feed Water Heater Designed for 20 Lb. Pressure

Feed water passes through a 300,000 lb. per hr. Hoppes heater which is operated at about 5 lb. pressure although it was designed to withstand a pressure of 20 lb. per sq. in. A flow meter on the heater records the total feed flow to the boilers. Three Roturbo feed pumps take water from the heater and deliver it to the boilers. These pumps were manufactured by the Manistee Iron Works and each is rated at 300 gal. per min. against a head of 415 ft. These pumps are direct connected to Westinghouse non-condensing turbines which operate at 2740 r.p.m. The discharge of these pumps is controlled by Copes governors. Magic boiler compound is pumped directly into the main feed water main.

Demand for low pressure steam is unusually high in the manufacture of salt and with the present arrangement of low pressure piping there is a tendency to rob the heater of the steam needed to heat the feed water. It is planned to locate a valve in the low pressure main between the heater and the first bleeder turbine. This valve will

FIG. 12. BUS STRUCTURE BACK OF THE MAIN SWITCHBOARD

then be opened just enough to pass to the manufacturing plant such auxiliary exhaust steam as is not required by the heater; this will cause the bleeder turbines to take more of the low pressure steam load. At the present time some high pressure steam is being used to bring the feed water temperature up to about 200 deg. F.

All high and low pressure piping is placed below the main operating floor in both the turbine and boiler rooms. All valves throughout the plant were made by the Lunkenheimer Co. with the exception of those on the air service lines which were furnished by Crane Co. Turbine lead and bleeder valves are operated from the turbine room operating floor by floor stands. Wherever it has been necessary to install chains for valve operation the valve wheel has been replaced with a Babbitt Steam Specialty Co.'s sprocket rim with chain guide.

Pipe joints are all of the Van Stone type. High pressure steam piping is covered with double standard magnesia and the low pressure piping is covered with standard thick magnesia. Cold water lines are covered with standard anti-sweat insulating material. All pipe covering was furnished by Johns-Manville, Inc.

Pipe service can be readily identified by a complete color scheme. A Bailey flow meter has been installed in the condenser room. It has been piped up so that it will record the steam flow to any one of the three generating units or either of two 8 in. outgoing high pressure steam lines.

This plant was designed and the construction was supervised by J. B. Shobert, consulting engineer. E. M. Ode is chief engineer in charge of operation.

Water Power Economy Overestimated

Cost of Hydraulic Power Greater than for Steam Power from Best Modern Plants, Opinion of Louis H. Egan, President Union Electric Light and Power Co., St. Louis, Mo.

LOCATION of super power plants at the mines and converting all coal into electric current for transmission is economically unsound, for the cost of getting the water for condensing purposes is too great. It would obviate the hauling of coal, except that needed for heating, but the weight of water needed is greater than that of the coal. As an instance, in the Cahokia plant, now under construction, the plant will need four times as much water as coal every day and the plant had to be located where there was plenty of water. Seldom is there enough water near a mine mouth, so it would have to be pumped from wells or rivers over a considerable distance. It is easier to haul coal than water, also, in most cases, the coal would have to be taken some distance from the mine to the plant and after the coal is once in the cars, it makes but little difference whether it has to be hauled 20 miles or 200.

Mr. Egan gave figures to show that there is no danger of a coal shortage. The United States Geological Survey, The Bureau of Mines and the Illinois Geological Survey have agreed within the last two years that in the Illinois seam No. 6 there is coal enough so that, if mined to only 55 per cent, it would supply the United States for the next 100 yr. That is only one of the mines in one state and coal is being mined in some 28 states. Mr. Egan stated it as his belief that power plants can and will use coal for the next 10,000 yr.

As to hydraulic plants, he made comparisons of costs, showing that the cost of building water power installations is about double that for steam plants. Adding the cost of transmission lines to bring the power where it is wanted and allowing a loss of energy of 15 per cent in transmission, he showed that to deliver energy from hydraulic plants to a community requires about four times the investment for steam-generated energy. If steam plants continue to improve their performance, he believes that they will make the hydraulic plant an uneconomical means of getting power.

He believes it reasonable to expect that further improvement of the steam plant will reduce the cost of generating power to two-thirds the present figure. Steam plants will continue to expand. The Cahokia plant has three times the year-round capacity of the much-talked-about Muscle Shoals project and in Chicago a plant is now being considered which will be double the size of Cahokia. The popular idea is to build a hydraulic plant, then sit on the bank and see the dollars roll in but the cost of building is so great that the interest charges approach the danger line.

Correct Lubrication for the Steam Turbine

Operating Methods, Causes for Breaking Down of the Oil and Specifications for Suitable Oils Are Discussed. By Claude C. Brown

DUE to the large size of the units employed in the present day practice of steam turbine installation, and the high speed at which these units are operated, the problem of correct lubrication is one of paramount importance. In fact, the advanced improvement in the methods of lubrication and ventilation have assisted, in a great measure, in bringing the development of the steam turbine to its present highly efficient state.

Correct lubrication of a steam turbo-generator is fully as essential a factor for its efficient and continuous operation as any other one element and too much care cannot be given to the correct design and maintenance of the lubricating system.

In order to secure the best results, the turbine oil in the circulating system should be kept as free as possible of foreign impurities such as scale, dirt, etc., entrained air and water, and should be kept as cool as possible and be of the highest grade.

It is possible to obtain high grade oils, especially manufactured for turbine lubrication. Such oils are the least affected by the presence of air, water and other impurities and are less likely to become broken down under the high temperatures and adverse conditions obtaining in many circulating systems than are those oils of cheaper or lower grade. Again, a good oil can be filtered and refiltered and has the necessary body for re-use many times over before it becomes necessary to discard it for further use.

Cheap or low grade turbine oil is a poor investment. Immediately upon being subjected to the high temperature and other severe operating conditions regularly met in practice, it proceeds to become oxidized and breaks down. This oxidation and breaking down which manifests itself by a darkening in color of the oil, an increase in viscosity, a burnt smell, a throwing down of a slimy and also of a hard black deposit and an increasing percentage of petroleum acid, immediately causes a greater heating in the turbine bearings, which in turn, causes the oxidation to proceed at a greater rate. This condition soon develops into a vicious cycle which, if not quickly checked, not only ruins the oil in the system but may cause serious damage and injury to the equipment.

At one time the writer witnessed a case where a sugar refining concern had installed a number of small turbo-generators which operated at a speed of 3600 r.p.m. The lubricating system of these turbines was filled with a low grade lubricating oil and in a short time it was necessary to take the machines down one at a time and scrape out the bearings, oil reservoirs, oil pumps, oil lines and the entire lubricating systems. The cheap oil had become oxidized and broken down, coating the entire circulating system with a hard, black deposit. It is clearly obvious that the purchase of cheap, low grade lubricating oils for use with steam turbine plants, is a short sighted policy, not only false economy, but decidedly detrimental to the apparatus and its operation. It is a practice that no first class chief engineer would tolerate.

Specifications for Lubricating Oils

High grade turbine oils should be composed of pure mineral hydro-carbon, free from tarry, slimy or saponifiable substances, acids, soaps or thickeners, water, dirt, grit or other suspended matter. They should have a specific gravity of from 0.860 to 0.880 at 60 deg. F. and a viscosity, as determined by the Saybolt viscosimeter, at 40 deg. C., not greater than 228 sec. They should have a flash point not below 300 deg. F. as indicated by an open cup tester, and should be incapable of forming an emulsion with water.

Initial Filling of Circulating System

Upon the completion of a steam turbine installation and before the initial filling of the circulating lubricating system has been made, every precaution should be taken to remove all possible grit, scale, core sand, waste, chips, filings, and other foreign matter from the system. All reservoirs, tanks, pumps, coils and oil lines should be thoroughly washed out with distillate and carefully cleaned and dried. Such precaution will remove a large part of the foreign matter in the system and will invariably prevent much future difficulty and possible injury to the bearings that is sure to result from a careless and negligent start.

For the initial run, the system should then be filled with a high grade turbine oil. After starting the turbine, close and constant attention should be paid to the lubricating system and note taken of the temperatures, viscosity of the oil, and its color and clearness. After a period of 150 hr. operation, the entire initial charge of oil should be removed from the circulating system and the entire system should again be thoroughly cleaned. The second cleaning at this time is necessary on account of the penetrating and cleaning effect of the hot turbine oil, which will loosen scale and foreign matter that was not removable at the time of the first cleaning.

A new charge of turbine oil should then be put in and the operation of the turbine resumed. The removed oil should be put through a good filter, and after all air, water, dirt and other foreign matter have been removed, it may be used for subsequent make-up additions. Should this initial charge contain a large quantity of impurities, the filtering of the oil will be facilitated by the use of a steam-heated separating tank.

Adding Make-Up Quantities of Oil

Make-up for lost oil due to leakage and evaporation will vary according to the size of the installation, the speed at which the units are operated, the surrounding temperature and a number of other operating conditions. As a rule, the quantity of this make-up will be small, and it should be added at frequent and regular intervals in such quantities as to keep the circulating system filled with oil. There is a limit, however, beyond which the practice of adding new oil to the old oil in the system should not be carried. As the oil in the system grows older in service, it will gradually darken in color and become worn out due to decomposition and the formation of petroleum acids and will have a steadily decreasing value as a lubricant. Close attention should be paid to the condition of the oil and as soon as it shows a decided acid reaction under test, it should be removed in its entirety and the system filled up with an entirely fresh charge of oil. The length of time that should be allowed to elapse between these entire renew-

als varies, of course, with the installation and the operating conditions, but in no case should it exceed 6 mo. of constant operation.

Oil Temperatures

Normal temperature of the lubricating oil in the circulating system of a turbine or a number of turbines that are supplied by a lubricating system, varies a great deal with the type of the system installed, the type of the turbines and the conditions under which the whole is operated. When a turbine is started up after having been shut down, the temperature of the oil in the circulating system gradually rises and finally becomes constant. When the turbine is started from cold this may take from 4 hr. in the case of a small unit to 24 hr. constant running in the case of larger installations. This temperature rise is due both to the friction of the bearings and to the heat in the bearings communicated through the shaft and frame from the steam.

In no case should the temperature of the circulating oil leaving the bearings be allowed to exceed 130 deg. F. as temperatures above this point tend to oxidize and break down the best of lubricating oils. There are, of course, installations where this limit is exceeded but such excess invariably results in low efficiency of lubrication and short life of the lubricating oil.

Practically every turbine circulating oil system contains an oil cooler, consisting essentially of a coil or coils through which the oil is pumped on its way to the turbine and which is surrounded by cold circulating water. Most of the heat that is absorbed by the oil in its passage through the bearings of the turbine is removed by means of this cooler. The resultant temperature of the oil depends partly upon the temperature of the cooling water used, but principally upon the size and capacity of the coils in the cooler and the velocity of the oil through them. The cooling water should be pumped through the cooler at a low pressure, and should be as clean as possible. Frequent inspections of the exterior and the interior of the cooling coils should be made and all deposits removed, as any deposit of scale or dirt on the exterior or any deposit of carbon, sludge or slime on the interior of the coils will greatly reduce the effectiveness of the cooler.

In order to keep a constant check upon the condition of the oil and the efficiency of lubrication, hourly readings of temperatures should be made of oil supplied to turbine reservoir, leaving each bearing, leaving gears in case of reduction geared turbine, entering cooler, leaving cooler, of cooling water entering cooler, and of cooling water leaving cooler.

In installations where the main bearings of the turbine are water-cooled, experience has shown that the bearing temperatures are lowered about 10 deg. F. In some installations the main bearings are oil-cooled, the oil passing through the cavities of the bearings before entering the bearing surfaces. This practice, however, is not common.

Broken Down Oil

Even the best of hydrocarbon oils have a limited life when used in the circulating systems of the present day installations. After having been filtered and re-filtered, used and re-used, even the highest grade of oil will eventually become worn out, lose its lubricating value and have to be discarded as far as turbine lubrication is concerned.

The length of serviceable life of a lubricating oil when used in a circulating system, is greatly dependent upon the quality of the oil. A low grade or unsuitable oil breaks down and goes to pieces after a very short period of service. A high grade oil will give, under normal operating conditions, good service for some 6000 working hours, while severe and unfavorable operating conditions may limit its useful life to 3000 working hours.

Broken down oil accumulates as a slime on the inner surface of the cooling coils of the cooler, and unless this deposit is removed it will greatly decrease their cooling efficiency. Broken down oil also accumulates in the form of a black, hard carbonaceous material in addition to the slime and forms in the oil lines to the bearings, in the bearings themselves and, in installations where the circulating oil is used as the operating medium of the turbine governor, this hard deposit is likely to clog and stop up the tiny ports of the governor mechanism thereby seriously hampering its operation.

Breaking down of the lubricating oil is the direct result of several causes:

1. Excessively high oil and bearing temperatures.
2. Static electricity from the generator shaft.
3. Solid impurities in the oil.
4. Entrained air in the oil.
5. Entrained water in the oil.

1. Excessively High Oil and Bearing Temperatures

Where the lubricating oil is circulated rapidly through the circulating system, the service is particularly hard on the oil due to the fact that the oil is forced into the rapidly rotating bearings under a pressure varying from 25 to 85 lb. per sq. in. It is readily appreciable that the film of oil between the shaft and the bearing metal, is extremely thin and that the conditions for its oxidation and break-down are thus ideal, particularly when assisted by the heat from the friction of the rapidly rotating shaft and the heat conducted through the shaft from the turbine steam. The greater the oxidation and break-down, the greater the heat, and the greater the heat the more rapid is the oxidation and break-down. When an oil once starts to deteriorate, its life is short.

2. Static Or Induced Electric Current from the Generator Shaft

Although it is not generally realized, there is an appreciable quantity of electric current which is inductively generated in the generator shaft due to the fact that it is continually within a reversing magnetic field. This current passes from the shaft through the bearings and the frame to the ground. The passage of this current, tends not only to heat up the bearings in some degree, but also to break down the thin film of oil on the bearing surfaces. In order that this current may be led from the shaft by some other route that through the bearings, all generator and turbine shafts should be equipped with a set of brushes, preferably carbon, of adequate size and surface area properly to handle this current.

3. Solid Impurities in the Oil

Due to the high temperature at which the oil passes through the circulating system, the oxidizing effect of solid impurities contained in it, is materially increased, particularly where the oil used is not of the highest grade. Such oxidation is evidenced by a quick darkening in color of the oil, a considerable increase in viscosity and the production

of a large percentage of petroleum acid. The oil, under these conditions, throws down a slimy deposit which lodges in the system, particularly the cooler and has a burnt smell. In addition if there is a slight leakage of water into the system the oil will emulsify badly. This explains why, when starting up a new unit for the first time, emulsification of the oil may occur as a result of the combined effects of the water, air and dirt present even though the oil may be of the highest grade. Every effort should be made to keep the oil in the circulating system free from impurities.

4. Entrained Air

It is a well recognized fact that entrained particles of air in any liquid, when exposed to pressure and heat, have a tendency to become nascent and act as a powerful oxidizing agent. The oxygen of the air in its nascent form is particularly active and will attack not only the liquid containing it, but all metal with which it comes in contact. This is noticed particularly in steam boiler practice when such air particles cause active corrosion in feed pumps, feed lines, and in the boilers themselves. The work of this nascent oxygen is evidenced by the pitting of the boiler drums, boiler tubes, headers, etc. Much work is now being done toward the de-aeration of feed water, thus removing the air before it reaches the economizers and boilers. Any entrained particles of air in the oil of a circulating system, when subjected to pressure and heat, act in the same way and tend to break down the oil. In fact, the lubricating oil, the bearings, lines, pumps and all other metallic parts of the system may be attacked.

Circulating oil in the system always contains more or less entrained air and when the temperature of the oil is above normal, that is, higher than 130 deg. F. this entrained air becomes active and has a strong tendency to oxidize the oil. This will be realized when it is remembered that the oil film in the bearings is extremely thin and that the air is present in fine bubbles which are intimately mixed with the hot oil. The effects of this oxidation are again readily recognizable by the black deposit, the slimy formation, the burnt smell and the formation of petroleum acid.

In order to prevent the entrainment of air in the oil of the circulating system, every precaution should be taken in the handling of the oil to eliminate churning, spraying or spouting of the oil. The oil of a circulating system should never be handled by a centrifugal pump, as it is a difficult matter to prevent air leaks around the shaft packing glands of such pumps. These leaks allow air to enter directly through the glands into the pump suction and into the pump where it is churned, broken up and frothed into the oil by the operation of the pump. The oil in circulating systems should be handled by means of a rotary plunger pump, a geared plunger pump or a duplex steam pump, properly fitted with cushion chamber to eliminate pulsations. The suction of the pump should be so arranged that at no time will it draw air.

All sprays and spouts and streams of oil dropping directly into the body of the oil, should be carefully avoided, as any such action tends to entrain air into the oil. Oil returns should not be allowed to drop from a height into the tank or filter, but should be led from the end of the return pipe into the oil body by means of a deflecting pan which will greatly diminish the splashing of the oil and the entrainment of air.

5. Entrained Water

Every possible effort should be made to prevent water from getting into the circulating system. Water has an emulsifying effect upon the oil particularly if the water contains impurities. Where considerable quantities of water leak into the circulating system and emulsification takes place, the mixture becomes yellow or brownish-yellow in color, loses its clear amber appearance and becomes opaque. If a sample is taken out and heated, it will separate into clean oil at the top of the flask, a more or less milky or cloudy water at the bottom and a spongy or slimy sludge between the two. The clean oil will be found darker in color and heavier in body than the original oil and will have a strong characteristic odor.

When subjected to rapid circulation, especially in small systems, the oil and water form an objectionable mixture which clogs the screens, baffles and ports, forms a slime on the interior surface of the cooling coils, accumulates in the clearance spaces throughout the system and tends to obstruct the passage of the oil, thereby cutting down the supply of oil to the bearings and causing a rise in bearing temperature. This mixture will generally become hard and may even cause a partial stoppage of the oil in the oil lines. In such cases, the increasing bearing temperatures indicate an insufficiency of oil supply which demands an immediate shut-down of the turbine to cleanse the system thoroughly.

Water may get into the system from several sources. One source is the steam leakage of the gland packing of the turbine. The steam blows past the packings into the housings of the main bearings where it condenses and mixes with the oil. Where the main bearings of the turbine are water cooled the water may leak from the water jackets in the housings, into the bearings.

Where the leakage of water cannot be avoided, a water trap fitted in a vertical position to the bottom of the oil tank has been found to be of good service. The water, circulating with the oil, will separate to some degree and drain into the trap. Once there, it cannot mix with the oil again and should be drawn off every 24 hr., letting the water and sludge run until clear oil appears.

In view of the unfavorable influence of water upon the oil, it is well to remove each day, from the bottom of the oil tank, from 10 to 20 gal. of oil for treatment in a steam heated separating tank and later in a good filter. The purified oil should be returned to the circulating system at the same time that a corresponding quantity is drawn off for treatment. In this way, the vitality of the oil can be maintained for a greater length of time than would otherwise be the case.

It is good practice to have a large quantity of oil in circulation with large settling tanks in which the oil will have time to settle and separate from the air, water and other impurities contained in it.

Wherever feasible, it is a good plan to incorporate a good oil filter in the circulating system so that at least a part of the circulating oil is passing through the filter at all times.

In case the cylinder head joint leaks, if the nuts on the studs across the head from the leak be slacked off and the nuts immediately adjacent to the leak be tightened up, followed by the tightening of the nuts loosened, in many cases the leak will stop.

Generation of Power with Factory Refuse

Wood Wastes and Other Refuse Are Used for Generating Steam and Producer Gas. By F. Johnstone-Taylor

ALTHOUGH WOOD is anything but an ideal fuel, there are many industries which, by reason of the amount of wood refuse produced, can make good use of it and by doing so reduce their power cost, while others may be so situated as to be partially or wholly dependent upon wood for fuel. In the first case, power can usually be obtained from what is often pure refuse which has no other value whatever; it may, in fact, be an actual encumbrance. In the second case, although the cost of fuel may be nothing more than the cost of cutting it, yet as the timber gets cut down so the question of transport arises and to employ wasteful methods of using it sooner or later proves a bad policy.

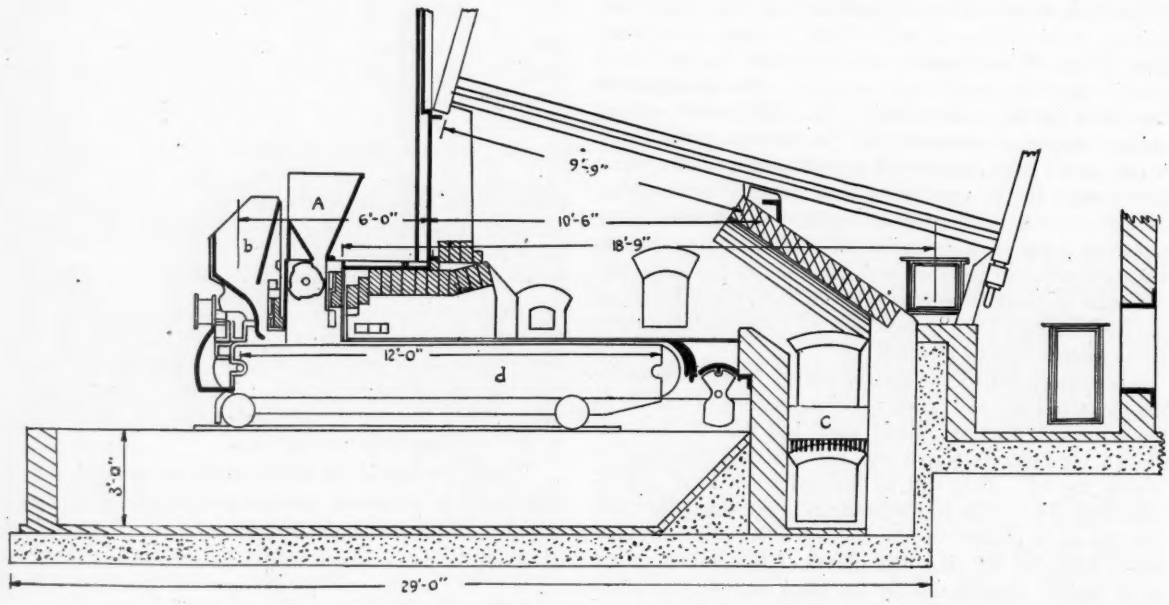


FIG. 1. FURNACE DESIGNED TO BURN WOOD SHAVINGS, COAL AND LARGE PIECES OF WOOD

What Constitutes Factory Refuse

In what is to follow, the term wood refuse is used in rather a wide sense and may be held to cover almost any class of combustible refuse which is reasonably dry. A large amount of such refuse is produced in tropical industries concerned with food production among which may be mentioned cocoanut shells, rice husks, mealie cobs and sugar cane refuse.

All these commodities are pure waste products and have more or less heating value which it pays to recover. Wood refuse from sawmills is of course such an obvious fuel as to need no comment. There are two main methods whereby heat can be recovered from this class of stuff and converted into power. The first is obviously to burn it under boilers; the second, not at first so obvious but often the more efficient procedure, is to gasify it for use in gas engines.

To fire boilers by just ordinary methods with any handy combustible refuse will generally prove an unsatisfactory procedure. If the supply of refuse is greater than the demand, the mere fact that combustion is going on under inefficient conditions might not be of much moment but the troubles inherent to using wrong methods cannot be ignored. A boiler suited to burning coal is usually entirely unsuited to burning combustible refuse, the furnace being too small. Unless, therefore, the boilers have been specially designed for dealing with this class of fuel satisfactory working will not be obtained.

Given a boiler or set of boilers entirely suited to this purpose, then, it will generally pay to lay out the plant on up-to-date lines. A sawmill, box or match factory is just the place for turning refuse to good account and as a pnuematic removal system is an essential part of a modern plant of this class, the material so collected can be discharged into hoppers over the boiler room from which it can be fed into mechanical stokers of a suitable type. The heavier material in the shape of odd blocks, logs and pieces collected about the works can be hand fired along with any other material not suited to mechanical stokers.

With a water-tube boiler arranged as in Fig. 1 an evaporation from 3 to 3½ lb. per pound of refuse available (average saw mill refuse) is usually obtainable.

This furnace, it will be observed, has a chain grate stoker of 80 sq. ft. area, the boiler being of the Babcock & Wilcox type having a heating surface of 3900 sq. ft.

In this particular instance, arrangements are made for burning coal should the amount of refuse be insufficient at any time. The wood hopper is shown at *A* and the coal hopper at *b*, the small supplementary furnace at the rear shown at *C* being for the consumption of heavy material. The chain grate stoker is shown at *d*. The principal dimensions are given, the width of the furnace being 9 ft.

Gas Production

In Britain, gas engines are used to a large extent for factory power purposes and for powers over about 20 hp. are generally combined with suction producers, the gas engine-producer combination having been brought to a high state of efficiency. Most of the gas engine builders have turned their attention to this matter of waste wood and other combustible refuse and they make great claims for its value as a source of gas power. These claims might be somewhat extravagant especially in the direction of belittling refuse as a source of steam power, nevertheless excellent results have been shown and some big plants are operating on this system involving single engines up to 400 b.hp. The suction gas producer designed for burning combustible refuse is much the same as that used with anthracite, some designs having a quick change arrangement so as to be suitable for either fuel. A typical arrangement is shown in Fig. 2.

Description of Producer

Referring to the lettering on the diagram the fuel chamber *A* is of large capacity, necessary to avoid too frequent charging. Before reaching the combustion zone of

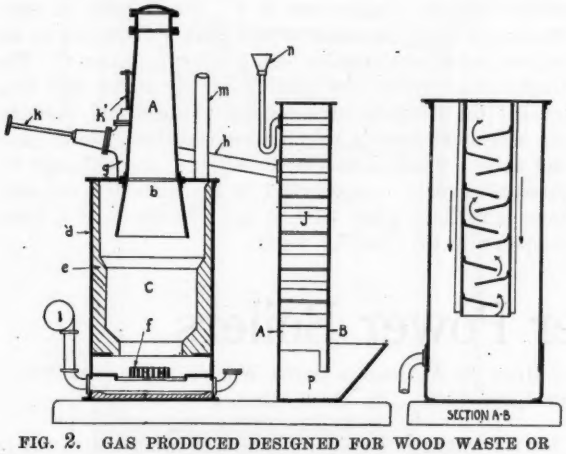


FIG. 2. GAS PRODUCED DESIGNED FOR WOOD WASTE OR ANTHRACITE FOR FUEL

the generator the fuel passes through distilling chamber *b*, where, subject to the heat of the surrounding gas it gives off volatile constituents which enrich the gas. Generator *c* is constructed of thick steel plates *d* lined with firebricks and packing *e*, doors being provided in the casing for the purpose of cleaning the fire. Firegrate *f* consists of loose firebars which can be removed and replaced through the fire doors, while poking holes are so arranged that any part of the furnace may be reached and the fire consolidated. Instead of the usual single outlet, the gas is taken off at two or more points on top of the generator by vertical pipes *g* and sloping pipes *h* which lead to the dust collector *J*.

Outlets are so arranged that an even draft is ensured through the fuel bed at all points and under all conditions of load. The outlet pipes *g* are provided with scrapers *k* by means of which tar and dust deposit can be removed at any time without interfering with production. From the top of dust collector *J* the gas passes to a rotary tar extractor before passing to a sawdust scrubber. A hand fan *l* is provided for starting the fire in conjunction with which is blowoff valve *m*. Water is supplied to the dust collector *J* by funnel *n* and the syphon pipe, the water used amounting to about 8 gal. per b.hp.-hr., but if water is scarce this can be filtered and circulated, about 1 gal. per b.hp.-hr. being required as make up.

Water seal *p* at the base of the dust collector enables the dust and a large portion of the tar to be deposited therein and withdrawn during the operation of the plant.

Operating Results

In determining the amount of power available from a given quantity of refuse, the amount of combustible used

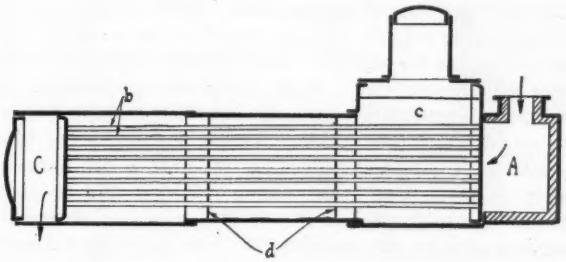


FIG. 3. BAFFLES IN HORIZONTAL EXHAUST GAS BOILER MAKE COUNTERFLOW HEAT EXCHANGE UNIT

per brake horsepower-hour is of importance. In some cases it will probably more than suffice for the power required so that if there is no sale for surplus power the fuel consumption is of no moment. On the other hand, if power wholly depends on refuse, then not only is the consumption per brake horsepower-hour of vital importance in the event of a likely shortage of fuel but the gas engine-producer combination can without doubt show better results per ton of combustible than any steam plant. The following figures are approximate consumptions in pounds per brake horsepower-hour for different fuels used in this way:

Wood refuse, 2½ lb.
Sugar cane refuse, 3 lb.
Olive refuse, 2 lb.
Mealie Cobs, 3½ lb.
Rice husks, 4 lb.
Cocoanut shells 2 lb.
Locomotive smoke box char, 2 lb.

The following actual fuel consumptions are taken from tests:

(1) Fuel. Dry wood cut in rough blocks.
Engines. 4-cylinder horizontal 300 b.hp.
Fuel consumption 80 per cent full load 2.07 lb. per b.hp.-hr.
Fuel consumption guaranteed 2.23 lb. per b.hp.-hr.
Calorific value of gas 161.5 B.t.u. per cu. ft.

(2) Fuel, Wood refuse.
Engine 140 b.hp. 2-cylinder horizontal.
Fuel consumption 2¼ lb. per b.hp.-hr.
Calorific value of gas 158 B.t.u. per cu. ft.

(3) Fuel. Smoke box char.
Engine 120 b.hp. 4-cylinder vertical.
Fuel consumption 2.13 lb. per b.hp.-hr.
Calorific value of gas 115 B.t.u. per cu. ft.

(4) Fuel. Rice husks.
Engine 50 b.hp. single cylinder horizontal.
Fuel consumption 4¼ lb. per b.hp.-hr.
Calorific value of gas 138 B.t.u. per cu. ft.

Figures given in (1) are of considerable interest as the plant, situated in South Africa, depends wholly on wood fuel cut and transported some distance. There are four engines each of 300 b.hp. These generate electricity for a mining installation. The gas plant which has a total capacity of 1400 hp. replaced a steam plant and is stated to have shown a saving of $14,580 per month in power costs.

Gas Storage, Boiler Firing by Gas

As its name implies, the suction producer depends upon the suction of the engine for the necessary flow of air into and gas out of the producer. This arrangement is in most cases entirely suitable, but of course precludes any reserve of gas for starting, which is really desirable in the case of large engines. It is a perfectly easy matter to work these producers by an exhauster and to store the gas in an ordinary gas holder. With a supply of gas thus available, if steam is required a gas fired boiler immediately suggests itself. In passing it might also be mentioned that with engines of any size quite an appreciable amount of heat can be recovered from an exhaust heated boiler.

Apart from this there is the question of burning the gas in boilers. From a point of view of economical power production, to produce gas and then burn it in boilers does not present an attractive proposition as compared with utilizing it in gas engines. As most industries require steam, however, if the requisite amount can not be obtained from an exhaust heated boiler then a gas fired boiler becomes of value.

While boilers of the water tube type and especially of the vertical water tube type are specially suited to burning large volumes of blast furnace and coke oven gas, for raising comparatively small quantities of steam from producer gas, fire tube boilers of a special type generally show the best results.

Boilers of this class as typified in the Bonecourt-Kirke design have been scientifically designed as gas burning boilers, a specially high velocity through the tubes being one of the essential features. They are based on the discovery that in the recovery of heat from gas the velocity of the gases and the shape of the heating surface are all important items.

These boilers, which have very long, small diameter fire tubes require little or no foundation or brickwork, and having induced draft the stack becomes merely a light steel tube. With this type of boiler, provided the gas is clean and supplied at a constant pressure, an evaporation of 1 lb. of water from feed water at 60 deg. F. converted into steam at 100 lb. pressure is secured from 13 cu. ft. of gas of calorific value 100 B.t.u. per cu. ft., a higher rate, of course, resulting from gas of higher calorific value.

An arrangement for an exhaust gas boiler for utilizing the waste heat from gas engines is shown in Fig. 3 and has proved an efficient type. The hot gas enters at *A*, passes through tubes *b* to exit *C*. The boiler is divided into three sections by the diaphragms *d d*. Small holes in each diaphragm allow the water to pass from the cold end to the hot end, actual evaporation taking place in section *C*. The diaphragms preclude circulation of the water and thus prevent the temperature becoming uniform and ensuring the maximum possible temperature transfer between gases and water. Steam is generated only in *C* and although the pressure in each compartment is the same the temperatures differ, the gases passing out through *C* at a lower temperature than boiling water.

Burning Oil Under Power Boilers

Localization of Heat in the Furnace Must Be Avoided if Brick Work and Boiler Maintenance Are to Be Kept Low. By R. F. Burke*

DISREGARDING structural differences, all oil burners may be brought under two classes; namely, steam or air atomizing burners and mechanical burners. The steam and air atomizing burners can be subdivided into three classes; namely, internal mixing, semi-internal mixing, and external mixing. All of the latter type burners employ steam or air pressure to break up or atomize the oil to such a degree as to permit rapid combustion. The mechanical burner uses neither steam nor air but atomizes the oil by heat, pressure and the mechanical construction of the burner.

Temperature of the oil at the burner has an important bearing on atomization and efficient burning of oil. This varies greatly with the gravity of the oil and the type of burner. Vary the oil temperature until you find the most economical condition, then stick as closely as possible to it. The proper temperature is by no means a fixed condition. With the standard grades of fuel oil now used, a temperature range of from 150 to 200 deg. F. is the best for steam or air atomizing burners and for mechanical burners the temperature should range from 225 deg. F. to 300 deg. F.

One of the most important items in the burning of fuel oil is the manner in which the air is admitted and regulated in the furnace. Various ways and means have been devised to bring the oil into intimate contact with the required amount of air but unfortunately some of those arrangements which usually give excellent results at first do not stand up, the air opening becomes distorted, choked with carbon and unconsumed oil with the result that the efficiency of the oil burning system decreases daily. The furnace, particularly in regard to the air distribution, should receive just as much attention as the burners.

It does not matter how well the burner does its work, if the required air is not admitted at the proper time and place the oil cannot be burned efficiently. Each burner should have its own individual air supply so that when the burner is not in use the air to any particular burner can be shut off. All dampers and air registers should be such that they can be set uniformly and the amount of air should be regulated by the boiler damper.

Flame Impingement Causes Tube Failures

Combustion must be complete before the gas comes into contact with the brick work or boiler heating surface. This is where the great difficulty lies in the burning of oil fuel. More brick work and tubes have failed from flame impingement than from any other cause. Where brick work fails rapidly in oil fired boilers it is not due entirely to high furnace temperature but to the fact that where impinge-

* Investigating Engineer, the Heine Boiler Co.

ment occurs the brick becomes saturated with oil, which soaks into the hot brick work and causes it to disintegrate.

Blow torch effect of the flame is augmented as the rating of the boiler and the velocity of the gas increase. If the furnace volume is too small for high ratings and continuity of service is required, it is advisable to operate the boiler with a higher per cent of excess air. One per cent drop in CO_2 will shorten the flame several feet and perhaps stop the impingement and minimize the danger of tube failure.

Furnaces should be designed for maximum load conditions. The furnace volume must be so proportioned that the gases are given time for complete combustion before coming into contact with the boiler heating surface or brick work. The length and width of the furnace is a fixed condition. The depth of the furnace or the height at which the boiler is to be set depends on the volumetric requirements. In figuring the furnace volume the path of combustion should be taken into consideration and not the entire furnace volume. Often furnaces are designed and the burners located in such a manner that there is a large dead space where no combustion takes place. In such a furnace the volume should be increased proportionally to the dead space. A combustion space of 1.5 cu. ft. per developed boiler horsepower will satisfactorily meet the average volumetric requirements.

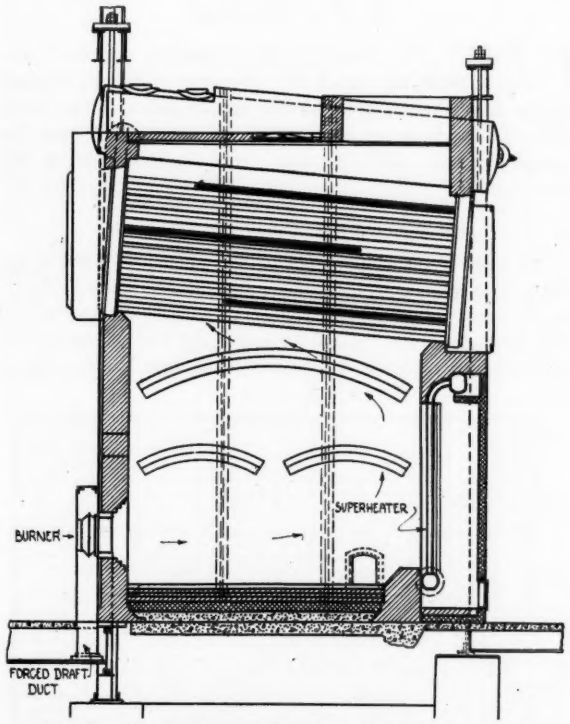


FIG. 1. FURNACE DESIGN FOR A NORMAL LOAD OF 200 PER CENT OF RATING

Portions of the furnace walls that are subjected to the highest temperature should be relieved of all possible strains and load for the reason that brick work begins to fail by plastic deformation before it reaches the melting point. The greater the load the lower the temperature at which the wall will fail. Arches should be used to sustain the weight of the brick work above the high temperature zone. This permits the brick work in the furnace to be repaired more readily and economically and it also increases the life of the furnace brick work by reducing the pressure on it.

Short Flame May Result From High Per Cent of Excess Air

Furnace length should be greater than the horizontal flame travel. Impingement on the side walls can be overcome to some extent with steam or air atomizing burners by pointing the outside burners away from the walls, but the length of the flame cannot be easily controlled except by operating the burners inefficiently with a high per cent of excess air. The furnace arrangement that will give the longest gas travel without direct impingement on brick work or boiler heating surface is the best and most economical for burning fuel oil. Bridge walls, checker walls, or target walls should not be used.

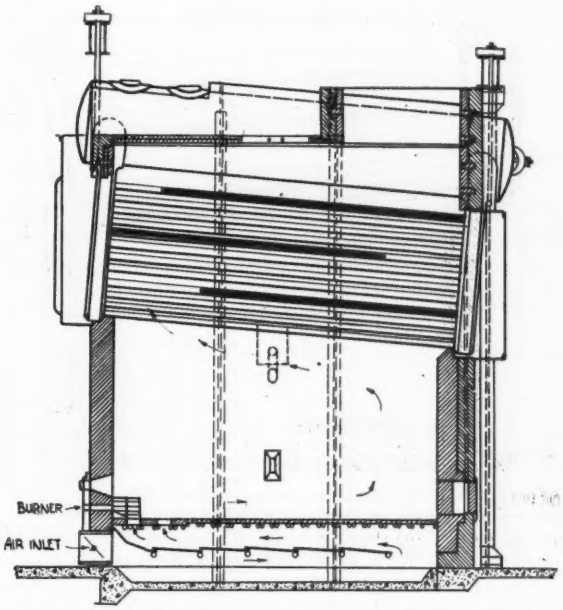


FIG. 2. FURNACE VOLUME OF 2620 CU. FT. FOR A 750 HP. BOILER TO BE OPERATED AT 250 PER CENT OF RATING

In Fig. 1 is shown a 700-hp. H-type Heine boiler fired with forced draft mechanical oil burners. The furnace of this boiler was designed for an ordinary load of 200 per cent and peak loads of 300 per cent rated capacity. A long flame travel is obtained without direct impingement on the boiler heating surfaces and the gas makes a complete turn in the furnace before entering the first pass of boiler. This affords ample time for complete combustion of the oil at high capacities. The furnace shown in Fig. 2 was designed for 250 per cent of rated capacity.

Figure 3 shows a 600-hp. H-type Heine boiler fired with steam atomizing burners. One installation in a textile plant consisting of four boilers with this furnace design, showed efficiencies of 80 to 83 per cent from rating to 200 per cent of rating. All boilers were equipped complete with the latest improved instruments. The gross daily efficiency including economizers averaged from 84 to 86 per cent. This compares favorably with the best efficiencies obtained in public service plants.

High efficiency cannot be maintained in any plant through guess work. The boilers should be equipped with

meters that will tell the amount of steam generated. The oil consumed should be metered or measured and a daily log kept which will show just what is being done. All data which relates to the economical performance should be recorded in this log for reference and information, which is essential if high efficiency is to be maintained.

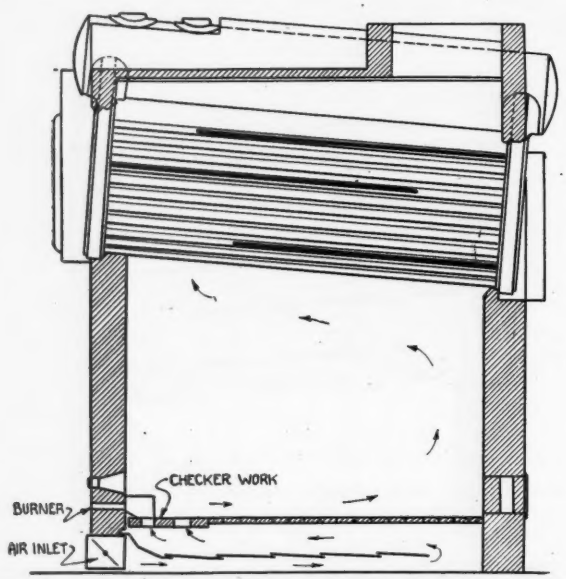


FIG. 3. EFFICIENCIES OF 83 PER CENT HAVE BEEN OBTAINED WITH THIS TYPE OF SETTING

In conclusion the following points are suggested on the operation of oil fired boilers:

1. Keep the entire oil burning system in repair.

2. Keep burners clean and in good condition.

3. A variation of oil pressure of over 2 lb. should not be allowed with mechanical burners.

4. Maintain oil temperatures steady and sufficiently high to secure proper atomization; low oil temperature is more wasteful than high oil temperature. With low temperature the oil will spray in small streams causing waste and serious injury to the furnace. Too high an oil temperature will cause pulsation.

5. Set all burners alike, noting that there is an equal distribution of the flame particularly with burners that are regulated individually.

6. For steam atomizing burners be sure the steam is dry.

7. Regulate the draft in furnace by the boiler damper, which should be operated and controlled from the front of the boiler.

8. Attach the draft gage to the furnace of all boilers. It should be located so that the draft indication can be read while operating the damper.

9. Air openings or checker work used generally in connection with steam atomizing burners should be maintained in good condition. The net area of all the openings should equal one square inch per developed boiler horsepower.

10. All oil burning systems should be installed with the return system of oil piping so that the oil can be heated to the desired point at the burners before any attempt is made to operate or start a cold boiler.

11. Do not operate with a clear stack, it is wasteful; indicating high excess air. Carry a grayish smoke.

12. It is very desirable for high efficiency that the flue gas be analyzed frequently so that the actual combustion condition may be known and the boiler operated with the lowest possible excess air.

Remember that satisfactory results and high efficiencies cannot be obtained with any kind of fuel without constant vigilance and intelligent supervision. This is particularly true in regard to the burning of oil fuel.

These facts relating to the combustion of fuel oil in boiler furnaces were presented before the Memphis convention of the N. A. P. R. E.

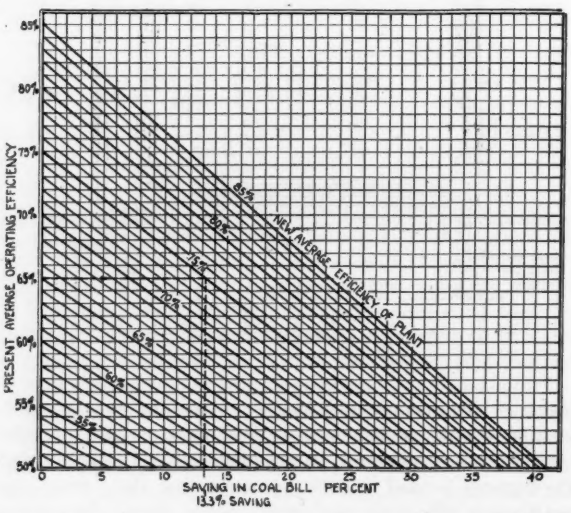
Saving Due to Improved Efficiency

By M. G. Flesher*

IN BUYING your new stoking equipment, you first have to give sufficient proof that the cost of the equipment is justifiable before you ask for stoker bids. Then, after receiving the bids the next thing, of course, is to pick the equipment that will best suit your requirements at the least cost.

Efficiency of Vital Importance

In view of the importance of the efficiency of the apparatus, you must make a comparison of efficiencies. How, by the comparison of efficiencies, do you figure the saving in coal that can be realized by installing new equipment in the place of your old equipment, also, how do you figure



PER CENT SAVING IN COAL BILL DUE TO INCREASED EFFICIENCY OF OPERATION

the saving in coal bill obtained with one type stoker over that of another make? Many of you merely take the difference between your present operating efficiency and that which you expect to obtain with new equipment or in comparing new stoking equipment, you take the difference between the efficiencies as guaranteed by the respective manufacturers. This, however, is not the net saving in your coal bill.

* Stoker Engineer, Westinghouse Electric & Manufacturing Co.

Coal Saving Formulas

Coal saving in per cent is equal to:

$$\frac{E_1 - E_2}{E_1} \times 100$$

Where E_1 = Efficiency of new equipment
E_2 = Efficiency of old equipment

In the following tabulation is given the derivation of the above formulas to show why the above is so:

Let H = heat in B.t.u. required per hour to evaporate the water at the rating which the efficiency guarantee is made.
H_c = heat content of coal in B.t.u.
E_1 = efficiency of new installation.
E_2 = efficiency of old installation.
C_1 = lb. of coal burned per hour new installation.
C_2 = lb. of coal burned per hour, old installation.

Then,

$$\frac{H}{E_1 \times H_c} = C_1; \text{ in like manner } \frac{H}{E_2 \times H_c} = C_2$$

$$\text{Saving in per cent} = \frac{C_2 - C_1}{C_2} \times 100$$

Substituting values of C_1 and C_2

$$\text{Saving in per cent} = \frac{\frac{H}{E_2 \times H_c} - \frac{H}{E_1 \times H_c}}{\frac{H}{E_2 \times H_c}} \times 100$$

$$= \frac{E_1 - E_2}{E_1}$$

A Typical Example

In order to show more clearly the relation that exists between efficiencies when speaking of economy or saving in coal, I have plotted the accompanying curve. As an example of its use, let us say you have a battery of old boilers set in combination with hand fired furnaces with an operating efficiency of 65 per cent. You want to improve this efficiency by replacing your old and inefficient equipment with that which is much more efficient. You investigate and find that by the installation of new stoking and boiler equipment you can raise the efficiency of your boiler room up to 75 per cent. Starting at 65 per cent on the ordinate as your present efficiency, cross over to the 75 per cent line as your new efficiency then down to the abscissae, which gives you the per cent saving in your coal bill. In this particular example it is 13.3 per cent and not 10 per cent as some are prone to believe.

Another Method

Another way of looking at this is to start with the proportion that coal burning rates for a given rating are inversely proportional to the efficiences, or

$$\frac{E_1}{E_2} = \frac{C_2}{C_1} \text{ where}$$

E_2 = Original efficiency
E_1 = Improved efficiency
C_2 = Represents original coal burning rate, or 100 per cent
C_1 = Improved coal burning rate in per cent of original rate

If the efficiency is improved by a certain amount then the coal consumption is likewise reduced. Taking the example above:

$$\frac{75}{65} = \frac{C_2}{C_1}; \; C_1 = \frac{65}{75} C_2$$

C_1 = 86.7 per cent $\times$ C_2 or the Coal Saved = 13.3 per cent

It follows from this inverse proportion that if the efficiency is increased from 65 per cent to 75 per cent then the coal burned is reduced to (75 — 65) ÷ 75 or 13.3 per cent.

To Regulate Fuel Expense, Control Draft

Proportion of Air Supplied to the Fuel Burned is Controlled by Draft Regulation. By James T. Beard

TOO FREQUENTLY the boiler house is a much neglected department of the average industrial plant. Although unusual care is taken to control and regulate the processes of manufacture in the production departments of the mill, the management of the boiler room is too often left to work out its own salvation.

Even the engine room, secondary as it is in the minds of the production heads, fares better than the boiler plant, for it is usually equipped with suitable indicators and instruments or gages for the information of the chief.

In too many cases the only instruments in the boiler room are the steam pressure gages required by law. How, then, is the engineer or fireman going to know what conditions are best for economical operation, or how is he going to be able to maintain those conditions, even if he does know?

Draft Control Essential for Coal Economy

One of the most important factors in the maintenance of an even distribution of load among the various boiler units, the economical operation of the individual units, and in cutting excessive fuel and power losses in the steam department, is the proper control of the draft necessary for burning the coal. Improper control of the air supplied to the fires may result in increased coal consumption, decreased capacity of the boilers and high maintenance costs of the furnaces.

When the fireman has nothing to guide him, other than the pressure gage, it is but natural that he should open up the boiler damper or throttle valve of the blower engine when the steam pressure drops, in order to speed up combustion and make the boilers deliver more steam. In doing so he is entirely correct, but there are other considerations he must allow for or his efforts will be wasteful, in spite of the fact that he delivers the extra steam required.

The amount of steam delivered in a given time depends upon the coal burned in that time and upon the proportion of this heat that is absorbed by the water in the boiler. To burn the coal at all, air must be supplied to the fuel bed. The resulting combustion develops a given temperature in the furnace.

If too much air is supplied the furnace temperature is cooled down. The quantity of air for best economy depends upon the thickness of the fuel bed. When the steam

pressure drops, therefore, the fireman must not only open the damper or speed up the fan, but he must also see to it that his fuel bed is thick enough and adequate for the increased load. If it is too thin, the cold air will rush through it and cool off the furnace, instead of burning the coal faster. Considerable fuel waste will naturally result.

Height of Stack Limits Strength of Draft

In some plants, particularly hand-fired plants, air is supplied to the fires by the natural draft of a stack. The

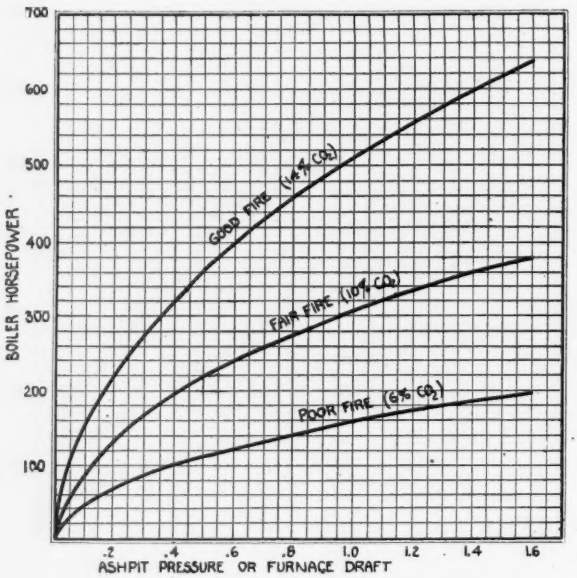


FIG. 1. VARIATION OF A 500-HP. BOILER OUTPUT WITH FURNACE DRAFT AND PER CENT CO_2 WHEN USING NO. 3 BUCKWHEAT

strength or amount of this draft will depend upon the height of the stack, the temperature of the flue gases and other factors, and must be sufficient to draw these gases through the breeching, through the boiler setting, besides drawing the air itself through the fire bed.

Natural draft is regulated or controlled by means of the main stack damper and also by means of individual

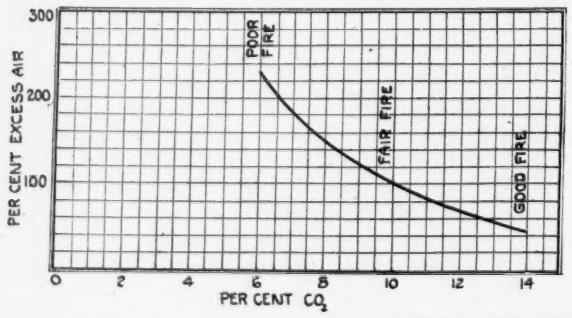


FIG. 2. LOSS DUE TO EXCESS AIR AS MEASURED BY THE PERCENTAGE OF CO_2 IN THE FLUE GASES WHEN BURNING ANTHRACITE

dampers on each of the boiler units. When the steam pressure drops the damper is opened, the draft is increased, coal is burned (if the fuel bed is in the proper condition), a greater heat is released in the furnace and more water is evaporated in the boiler. When the steam pressure is up, the damper is closed and the reverse takes place.

Where natural draft is used there will always be a vacuum in the fire box and the air will be sucked from the boiler room through the fire bed. The amount of vacuum to do this will depend upon the thickness and resistance of the fuel and grates. If the boiler is operating at full capacity and the fireman has just coaled up, the draft will be high. As the coal is burned to ash, the bed gets thinner, spots will appear where little resistance will be offered to the flow of air and the suction in the furnace will grow less and less until the fireman coals up again.

When the suction or draft in the furnace is low, very little coal is being burned. If the damper is full open under these conditions, cold air is rushing into the furnace and the boiler cannot operate at best economy. It is logical,

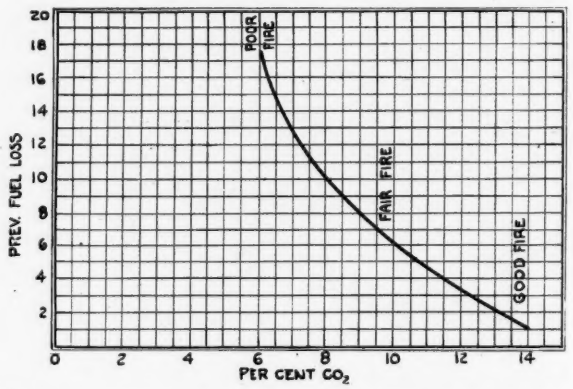


FIG. 3. PREVENTABLE FUEL LOSS INDICATED BY CO_2 IN FLUE GASES, BURNING ANTHRACITE

therefore, as well as economical to fire little and often if flat grates are employed, the object being to maintain the thickness of the fuel as nearly uniform as possible. Infrequent firing and long periods of rest mean wide variations in the furnace temperatures and poor boiler economy.

Stokers Are More Efficient Than Grates

Stokers are designed to maintain that constant and uniform feed of coal that is not possible with hand-fired flat grates. For this reason stokers are always more efficient than grates. The fuel bed thickness is uniform, furnace temperature uniformly high and boiler efficiency a maximum.

It is not possible for any fireman correctly to judge his drafts by the mere inspection of the fire nor by looking at the steam gage. He should have a visible indication before him at all times. The draft gage is a simple and inexpensive instrument and gives accurate and instant information of the draft through the fuel bed and the condition of the fires. When the furnace conditions are best it will show a maximum reading; but when the combustion efficiency begins to drop the gage reading will also drop and indicate that the fires need attention.

Stokered plants are usually equipped with forced draft apparatus. Air is forced through the fire bed under pressure developed by a power driven fan or blower. The draft control for such an installation is slightly more complex. As before, there is a damper in the stack and in each individual boiler unit. In addition, there is usually a damper in the duct which carries the air from the fan to the ashpit un-

der the fuel bed. The air duct damper is not used, however, except when a unit is cut out of service, the forced air supply being regulated by controlling the throttle valve of the blower engine, or the rheostat, if it is a motor drive.

Precisely the same principles apply to the control of drafts as in natural draft plants, as regards thickness of fuel bed, economical draft or pressure for highest efficiency, etc. These factors depend upon the capacity required of the boiler, grade of fuel burned and other factors. Higher boiler capacities are possible with forced draft than with natural draft, since the suction available in the latter case is limited by the height of the stack, while any pressure within reason may be secured in the former instance by the selection of a blower of suitable capacity.

Referring to the curve in Fig. 1, it will be seen that the number of pounds of coal burned per square foot of grate

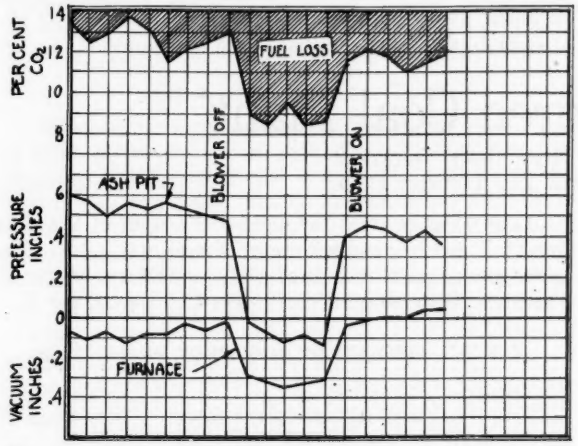


FIG. 4. POOR REGULATION OF UPTAKE DAMPER CAUSES EXCESSIVE FUEL LOSSES

per hour increases in a definite and fixed manner as the air pressure in the ash pit builds up. The horsepower developed by the boiler increases also in the same definite way. With a poorly conditioned fire, however, the capacity of the boiler is far below its capacity with a properly conditioned fuel bed, assuming that the ashpit pressure remains the same. When the draft gage reading is below normal it indicates that the fire is in a poor condition and that the boiler is not developing the capacity that it should.

It indicates also another serious operating condition. The excessive amount of air that is passing through the fuel bed is cooling the furnace temperature and is causing an actual fuel loss represented by the amount of temperature reduction. The amount of this loss depends upon the amount of excess air.

Correctness of Air Supply Indicated by CO_2 Percentage

This excess is best measured by testing the flue gases for the percentage of carbon dioxide they contain. When the fuel bed is in good condition and the boiler is operating at a high efficiency, the percentage of CO_2 will be in the neighborhood of 14. In the operation of the average industrial plant it may run as low as 6 or 8 per cent. The curves shown in Figs. 2 and 3 indicate the extent of this loss. The proper conditioning of the fires to obtain the highest possible CO_2 and best economy is, therefore, important. The proper regulation of the drafts by damper or blower control is equally vital.

Figure 4 shows what happens in a forced draft plant when the blower is shut off without adjusting the uptake damper to meet the new draft and combustion conditions. The load went off the boiler at "A" and, when the steam pressure went up the blower was shut down. Since the uptake damper was open, the suction from the stack pulled a vacuum in the furnace, drawing cool air into the setting

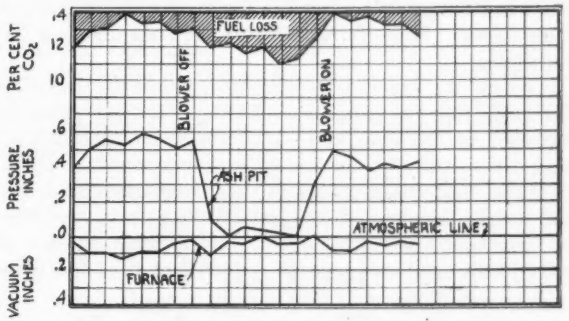


FIG. 5. GOOD REGULATION OF UPTAKE DAMPER IS INDICATED BY SLIGHT VARIATION IN CO_2 PERCENTAGE

through every crack and crevice it could find. The percentage of CO_2 in the flue gases dropped immediately resulting in a preventable fuel loss in spite of the fact that the fires themselves were in good condition. When the load came on again, and the blower was cut in once more,

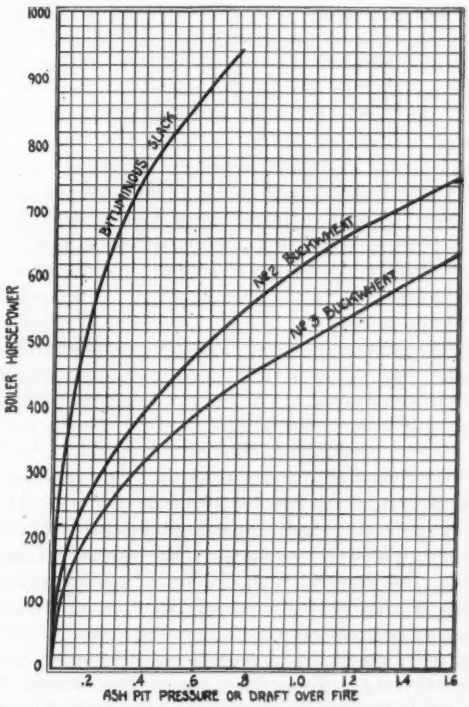


FIG. 6. VARIATION OF DRAFT REQUIREMENTS WITH DIFFERENT COALS UNDER A 500-HP. BOILER, ASSUMING 14 PER CENT CO_2

the vacuum over the fire was reduced and the operating efficiency immediately jumped up.

This wrong condition was remedied by closing the uptake damper when the blower was shut off,—not tight, but just sufficient to leave a slight vacuum over the fire. The

CO_2 then stayed up where it belonged and the boiler efficiency was materially increased. In the plant where this was done, a marked coal saving was effected in a short space of time.

In boiler house operation it is particularly desirable to avoid pressures in the furnaces. Dampers and blowers should be so adjusted that pressures cannot build up. When they are present, the tendency is to force the hot gases outward and the result is short life for the brickwork and furnace lining. High furnace repairs and maintenance are inevitable.

Where the expense is warranted, automatic recorders for measuring the percentage of CO_2 in the flue gases are valuable in checking and maintaining the efficiency of operation. Only by the use of such instruments in conjunction with the draft gages previously mentioned, can the correct thickness of fuel bed and best draft conditions be determined and maintained. By a small amount of experimenting it can soon be found what thickness gives the best reading of CO_2 and that thickness should be kept for normal boiler ratings. The draft gage reading should be noted when the fuel bed is in good condition. Readings decidedly lower than this indicate that the fires need attention.

Even under the best conditions, however, much depends on the efficiency of the human element. It is possible, however, to take the draft regulation out of the hands of the fireman and to make it entirely automatic. Suitable regulators, if properly adjusted, will operate to maintain the conditions that are known to give best and most economical results. The fireman then has merely to watch the draft gage and to make sure that his fires are at all times in good condition. If the common-sense thoughts discussed here are intelligently applied to the boiler house operation in the average industrial plant, marked savings can be effected in the coal consumption for steam power purposes. In many instances reductions in the coal bill of from 10 to 20 per cent have been accomplished.

Tests of a Powdered Coal Plant*

Efficiencies Above 77 Per Cent Obtained With Three-Pass Boilers and Illinois Coal

TWO TESTS, one of 48 hr. and the other of 9 da. duration, have recently been conducted by the fuel section of the Bureau of Mines, the Combustion Engineering Corp., and Stone & Webster (Inc.) at the pulverized-coal plant of the St. Joseph Lead Co., Rivermines, Mo. Test No. 1 was run at 200 per cent of boiler rating and with coal which had been passed through the drier. Test No. 2 was divided into two periods, one of 5 da. and one of 4 da. duration. During the former period the coal was dried, but in the latter the coal was pulverized and fired as received.

Bituminous coal from Southern Illinois, of good quality, for that district, was used. It was shipped as screening, and that part delivered to the pulverized coal plant contained little slack. The analysis of this coal as received, was as follows:

Moisture	6.6 per cent
Volatile matter	31.7 per cent
Fixed carbon	49.0 per cent
Ash	12.7 per cent
B.t.u. as received	11,520

Results Obtained in Tests

Two thermal efficiencies are given, the overall and that of the boiler only. Neither efficiency includes the power used in preparing and conveying the coal. The overall efficiency, Table I is the smaller because of the coal burned in the drier furnace, the loss of coal dust in drying, the loss of coal dust discharged from the mill vents, and the loss of heat in the pyrites removed from the mills; but it was only about 1.5 per cent less with dried coal, and negligibly less with undried coal. The overall thermal efficiency is almost identical with that obtained in tests of No. 9 boiler in Jan., 1921, made by engineers of Stone & Webster (Inc.). A summary of the results of these tests is given in Table IV for comparison. The results of test 1 are comparable with test 6 of Table IV, and the results of the first part of test 2 with dried coal compare with test 2 of Table IV.

*Abstract from technical paper 316, Department of the Interior, Bureau of Mines.

Table II shows that the dried coal output of the mills was 5.6 T. per hr., and with undried coal only 4.2 T. The power consumption with dried coal was 13.9 kw.-hr. per T. whereas with the undried coal it was 18.5 kw.-hr. per T.

TABLE I—SUMMARY OF RESULTS OF BOILER TESTS

Test number	1	[1]2	[2]2
Duration ..... hr.	48	119.22	93.28
Condition of coal when burned	Dried.	Dried.	Undried.
Rating ..... per cent	202	155	155
CO_2 ..... do	12.9	13.7	13.6
Temperature of flue gas ..... °F.	666	561	567
Temperature of superheated steam ..... °F.	546	525	534
Overall thermal efficiency, in per cent of heat in coal supplied to preparation plant	72.6	77.3	78.2
Thermal efficiency of boiler only in per cent of heat in coal supplied to boilers	74.4	78.8	78.4

[1]First 5 days. [2]Last 4 days.

TABLE II—SUMMARY OF RESULTS OF MILL TESTS

Condition of coal	Dried.	Undried.
Capacity ..... tons per mill-hour	5.6	4.2
Power required per ton ..... kw.-hr.	13.9	18.5
Moisture in coal as pulverized ..... per cent	4.9	6.1
Coal through 100-mesh screen ..... do	94.9	95.0
Coal through 200-mesh screen ..... do	75.0	76.0

TABLE III—SUMMARY OF RESULTS OF DRIER TESTS

Capacity per hour ..... tons	15.62
Moisture content before drying ..... per cent	7.53
Moisture content after drying ..... do	4.87
Power required per ton of coal ..... kw-hr.	1.68
Coal used in drying, per cent of coal dried	1.29

TABLE IV—SUMMARY OF RESULTS OF PREVIOUS BOILER TESTS MADE BY STONE & WEBSTER IN JANUARY, 1921

Test number	3	2	5	6
Duration ..... hours	21.3	22.5	26.0	19.75
Condition of coal when burned	Dried.	Dried.	Dried.	Dried.
Rating ..... per cent	103	152	181	205
CO_2 ..... do	15.4	14.5	12.3	12.9
Temperature of flue gases ..... deg. F.	465	528	586	609
Temperature of superheated steam .. deg. F.	494	500	501	520
Overall thermal efficiency, in per cent of heat in coal supplied to preparation plant	77.8	77.5	73.8	72.9

Results of drier tests are shown in Table III. The moisture content of 15 to 16 T. of coal per hour was

reduced by about 3 per cent. Only a low fire was kept in the furnace for it seemed as though only the surface moisture needed to be removed in the drier to enable the coal to pulverize easily. To dry one ton of coal, 25 lb. of coal was burned and 1.7 kw.-hr. used to operate the drier and necessary conveyors. To pulverize and convey the dried coal required 4.7 kw.-hr. less than to pulverize and convey the undried coal. Thus the energy saved in preparing and conveying one ton of undried coal was equivalent to 25 lb. of coal, and the energy lost was 3 kw.-hr.

Description of the Boiler Plant

There were two Stirling boilers, each having 7688 sq. ft. of heating surface, set singly and connected by a steel breeching to a 200-ft. brick stack. The furnaces were of the Lopulco design and each was equipped with two duplex, round nozzle burners. Each burner was supplied with coal from a separate feeder connected to it by a 3½-in. pipe. Air was supplied to the feeders under a pressure of 8 to 14 in. of water by a No. 7 Sturtevant steel pressure blower.

Method of Conducting Tests

Separate samples of coal were collected for every 50 T. at three points along the path of travel from the coal weighing scale to the feeder lines. The feed water was measured in two tanks, holding approximately 4330 lb. of water at 180 deg. F. The feed water was bad, and caused excessive priming in the boilers unless they were frequently blown off. For this reason George F. Weaton, chief engineer for the power plants, devised a method of continually blowing off the boilers. The quantity of water blown off was regulated according to the concentration of the solids in the water in the boiler; this concentration was continually indicated by a specially devised, simple but effective instrument attached to the blowoff pipe of each boiler.

During the tests the blowoff water was cooled by passing through coils immersed in cooling water, then discharged into a weighing tank and weighed. The weight of the blowoff water was deducted from the feed water, but the amount of heat the blowoff water absorbed was credited to the boiler. The pump leakage was caught, and its weight was deducted from the weight of the feed water.

Condition of Slag at the Bottom of Furnaces

In boiler test 1 during the first 12 hr. of operation the slag that had accumulated on the side walls fused, ran down, and spread over the bottom of the furnace. The slag at the bottom of the furnace remained molten until the end of the test; then when the boiler was shut down to remove the slag from the tubes the slag at the bottom solidified and could not be removed with slice bars and hoe.

In boiler test 2 the slag at the bottom of the furnace of boiler No. 9 melted again after about two days' operation, and remained molten until the end of the test; the slag at the bottom of boiler No. 8 became soft and sticky and could not be removed while the boiler was in operation.

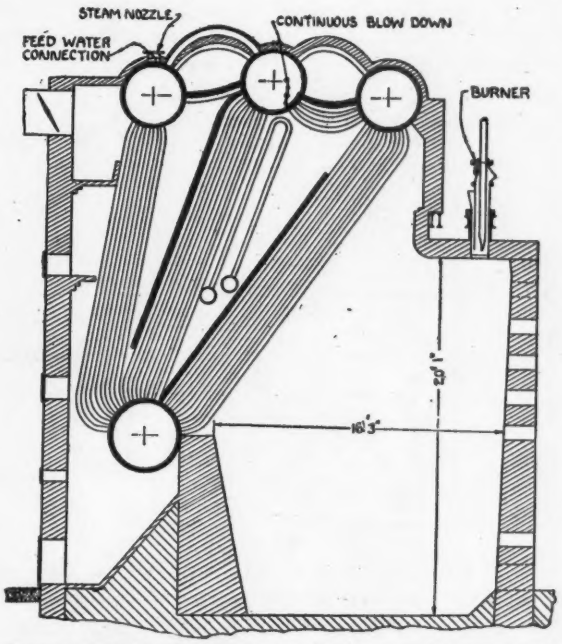
At the end of test 2, when boiler No. 9 was completely cooled down, men entered the furnace and removed the slag; it consisted of several layers 2 to 13 in. thick, totaling about 36 in. in depth.

Boiler No. 8 continued in operation at the end of test 2. In an effort to direct currents of air through the cleaning-out doors against the bottom of the furnaces these doors were completely opened and steel plates, with their lower edges 3 to 4 in. from the bottom of the openings, were placed in the openings at an angle. This attempt to keep the bottom of the furnace cool was unsuccessful.

At the end of test 2 the west wall about halfway up and the west half of the bridge wall of boiler No. 8 showed marked abrasion, more than at any other place in either boiler. The eastwall and bridgewall of boiler No. 9 showed considerable abrasion.

Efficiencies in these tests are low as compared with the results of the tests made at the Lakeside Station, Milwaukee, which gave boiler efficiencies 7 to 8 per cent higher than the two Stirling boilers of the Rivermines plant gave. The reasons for the higher efficiency of the Lakeside plant are:

1. Special provision of water screen and air-cooled hollow walls, to prevent erosion of furnace lining and the slagging of the ash at the bottom of the furnace, which made possible the operation of the furnaces with a low excess of air.



SIDE ELEVATION OF STIRLING BOILER AT THE RIVERMINE PLANT

2. The four-pass boilers of the Lakeside plant are much better heat absorbers than the three-pass boilers of the Rivermines plant, consequently the gases leaving the four-pass boilers have a temperature about 130 deg. F. lower than those from the Stirling boilers.

On account of these two features, the heat losses in the dry chimney gases of the Lakeside boilers are 7 to 10 per cent, whereas for the Rivermines boilers they are 12 to 15 per cent. For the hollow furnace walls of the Lakeside station the radiation losses are about 1½ per cent less than they are for the solid furnace walls of the Rivermines plant. The difference in these two losses nearly accounts for the difference in the efficiency of the two boiler plants.

When an attempt is made to operate the furnaces of the Rivermines plant with low excess of air and high CO_2 in the flue gases, the temperature in the furnace becomes so high that the ash at the bottom of the furnace melts and can not be removed while the furnace is in operation. The high temperature also causes excessive erosion of the furnace lining, because the melting point of the ash in the Illinois coal is so low that the ash melts completely at the high furnace temperatures, runs over the brick lining, and erodes the brick.

Diesel Engine Fuel Valves---I

ATOMIZATION IS AN IMPORTANT FUNCTION OF THE FUEL VALVE. BY H. F. BIRNIE AND R. C. BAUMANN

OF THE VALVES controlling the events and processes of combustion in the oil engine the fuel injection valve is the one in which the greatest individuality of design exists. The purpose of the injection valve is first to time the injection of the fuel oil in relation to the movement of the working piston and to control and regulate the rate of fuel delivery to the combustion chamber. Second it must atomize the fuel oil, i.e. break it up into minute globules. Third, it must distribute the atomized oil throughout the combustion space.

Let us consider the necessity of each of these functions briefly. The time at which combustion starts and the rate at which it continues is for all practical considerations

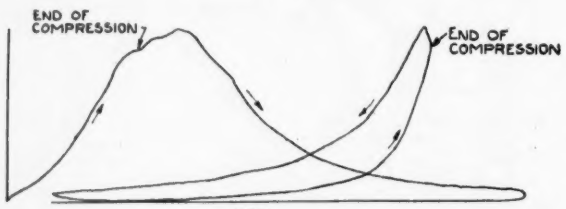


FIG. 1

FIG. 2

FIG. 1. TOO RAPID INJECTION OF THE FUEL ALLOWS THE CYLINDER PRESSURE TO RISE ABOVE THE COMPRESSION PRESSURE

FIG. 2. FUEL INJECTION THAT IS TOO SLOW CAUSES THE COMBUSTION LINE TO DROP

entirely under the control of the injection valve. If the valve is correctly designed and adjusted and the compression of the air charge in the cylinder is consistently high enough, burning should start each time at a uniform interval after the injection valve has started to open. It is not sufficient only to time the moment of initial combustion but the rate at which fuel is injected into the cylinder must also be carefully governed.

If the injection is too rapid the cylinder pressure will peak or rise above the compression pressure as shown in Fig. 1, or if it is too slow the combustion will not proceed at constant pressure as desired but the combustion line will droop as shown in Fig. 2. The burning instead of being completed early in the expansion stroke will extend more or less throughout the whole expansion stroke. This increases the temperature of the exhaust gases, decreases the thermal efficiency and increases the mean average temperature of cylinder walls and exhaust valve. The immediate results will be higher fuel consumption, troublesome exhaust valves and impaired cylinder wall lubrication. The methods adopted by different designers to regulate the rate of fuel injection will be considered in connection with the various valve designs. The purpose of atomization is obvious, it increases many times the surface of the fuel exposed to the oxygen of the air, hence insures rapid and complete combustion.

FUEL MUST BE THOROUGHLY MIXED WITH AIR

Distribution, the third duty of the injection valve, is functionally a furtherance of atomization. No matter how complete the atomization it will be of no benefit unless the atomized fuel particles are evenly distributed throughout the combustion chamber and thoroughly mixed with the air available for combustion. It must be kept in mind that there is present in the cylinder only a limited quantity of oxygen with which to sustain combustion. It is the duty of the fuel valve to bring the oil to the available air so that all the oil may find sufficient air for its combustion.

In the air injection engine the highly compressed injection air is not only the atomizing agent but it becomes also the vehicle for the atomized fuel which carries the

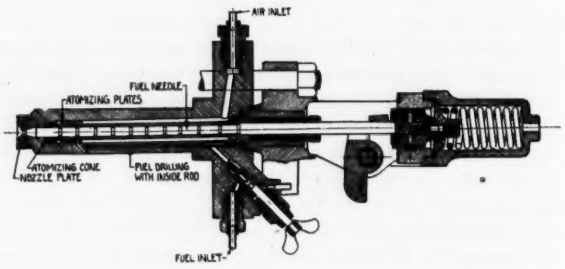


FIG. 3. SECTIONAL VIEW OF A PLATE ATOMIZER VALVE

atomized fuel into the cylinder and distributes it to all parts of the combustion space. The injection air rushing into the compressed air charge of the working cylinder creates a very violent turbulence or churning of the cylinder contents thus effectively mixing the fuel oil with the air charge.

One hears a great deal of late concerning "turbulence." A brief explanation of its use in internal combustion design may therefore be in order. Turbulence to the engine designer refers to the movement of the air charge in the combustion chamber at the end of the compression stroke. The upward movement of the piston on the compression stroke does not itself cause air currents of appreciable magnitude.

Eddy currents in the incoming air charge are caused by the air rushing into the cylinder, past the suction valve of the four stroke cycle engine or past the scavenge ports of the two cycle engine, during the suction or charging stroke. Some designers intensify this effect, in the case of four stroke cycle engines, by placing baffle plates in the intake passages which cause a whirling of the incoming air. These eddy currents, existing in the air charge before the beginning of the compression stroke, still subsist during and at the end of the compression stroke although they are damped out considerably by the compression so that they are hardly of sufficient magnitude to be major factors in the combustion processes which follow. Turbulence produced by these methods is not only of low intensity but

it is not directed to secure the best results. The air currents which exist whirl about at random.

Violent Turbulence May Cause Drop in Efficiency

While a certain degree of turbulence is desirable from the standpoint of accelerating combustion, an unnecessary amount is undesirable because of the lowered efficiency due to the increased cooling of the burning gases as they are whirled against the cold cylinder walls. If the turbulence is very violent the combustion instead of being accelerated may even be retarded. The minimum turbulence consistent with rapid and complete combustion will therefore give the highest overall efficiency. The minimum turbulence will be the one in which the air currents are directed to secure the best fuel distribution with the least air movement. Designers seek to produce and guide air movements in the combustion chamber by various schemes and devices which will be considered in connection with the valves with which they are used.

Air injection Diesel engines make use of two main types of fuel injection valves; (1) The open type, generally used on horizontal engines and (2) The closed type, generally used on vertical engines. The closed valves may be subdivided as (1) plate atomizers and as (2) Swedish or Hesselman design. Between the two subdivisions there are many modifications and individualities of design. The American engines are practically all fitted with the standard plate atomizer valve, the only prominent builder of stationary engines using the Hesselman design being the McIntosh & Seymour Corp.

Solid or airless injection valves may be classified as (1) the cup atomizer (referred to as Brons or Hvid), (2) the automatic spray valve and (3) the mechanically operated spray valve.

Details of Plate Atomizer Valves

Conventional plate atomizer valves of the air injection Diesel have three elements, i.e. atomizer plates, an atomizing cone and a nozzle plate. Each of these elements may be changed in shape, opening and, in case of the atomizing plate, in number to suit different grades of oil. The appearance and relative position of each of these elements in the fuel valve may be seen in Fig. 3 and Fig. 4.

Atomizing plates do not, as one might think, do all the atomizing. They prepare the oil and air mixture for atomization by dividing the oil and air into small streams. When the fuel charge is delivered to the valve it is deposited upon the top atomizer plate. When the needle valve opens the injection air rushing through the small holes of the plates carries along the oil with it after a short interval. The oil and air then pass through the atomizer cone and nozzle or burner plate into the combustion chamber.

One sometimes hears the contention that the atomizer plates should not be wiped completely clean of oil each time by the air but that there should be some fuel left adhering to the plates which will trickle down towards the fuel needle seat between injection periods. It is then supposed to collect around the needle seat and precede the air into the combustion chamber on the next lift of the needle and thus become the agent for initiating combustion. It is, however, hard to imagine how the oil has time to flow by gravity from the plates to the needle seat during the period between injections as for instance in the case of a four cycle engine turning 250 r.p.m. the needle lifts 125 times per min. The available time between injections is therefore less than one-half second.

Defective Valves May Cause Engine to Hunt

One of the first principles to observe in the design of a fuel valve is that the fuel oil should be delivered as close as possible to the top surface of the first atomizer plate and that the delivery must be directed to distribute the oil evenly around the whole circumference of the plate. It has been found that when the oil delivery ports in the valve body are set too far above the atomizing plate the engine will show a tendency to hunt at times. If the oil is a little too viscous it will stick to the walls of the valve cage instead of finding its way to the first atomizer plate.

As the valve opens the injection air will not strike the oil directly but will leave it adhering to the walls of the valve cage. The injection air thus enters the cylinder without fuel oil and consequently does nothing but hinder combustion by cooling the cylinder air charge. This results in mis-firing or at least firing of uneven intensity as evidenced by poor speed regulation of the engine.

As mentioned before there should be a small amount of fuel directly at the end of the needle, below the atomizer cone which will be pushed in ahead of the air as soon as

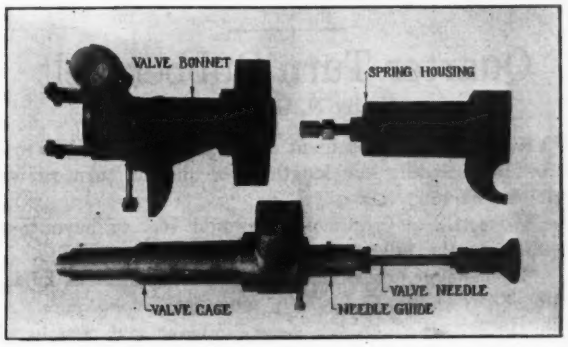


FIG. 4. ESSENTIAL PARTS OF A PLATE ATOMIZER FUEL INJECTION VALVE

the valve starts to open. This small pilot charge of oil coming directly into contact with the hot compressed air charge of the cylinder ahead of the cold expanding injection air serves to make the ignition of the main charge of fuel more certain. This small pilot charge of oil does not find its way to its position just above the fuel valve needle seat by dripping from the atomizer plates between injection periods but rather it is carried to its place by the last part of the injection air which passes through the valve as the latter is just closing.

One reason for hunting has already been pointed out, that is, too high a location of the oil entry ports in the valve cage; they should be placed as nearly as possible directly above the top atomizer plate. A second cause may be found in the collapsing of the oil column in the long vertical drilling inside the injection valve cage which conducts the oil from the upper part of the valve to its point of delivery about the atomizer plates.

Normally this drilling should be filled with a column of fuel oil at all times. Sometimes however this column collapses while the injection valve is open due to the reduced pressure inside the valve as the injection air rushes through the valve on its way to the combustion chamber. All the oil contained in the column then drains onto the

atomizing plates and thus constitutes an overcharge of fuel for this particular cycle. The following charge of oil will be only partially deposited upon the atomizing plates, most of it being required to again fill up the vertical conductor drilling. This trouble is overcome by placing a small rod in the drilling which reduces its area and increases the surface to which the oil may adhere. The same result would be accomplished in a more positive way by placing a small spring loaded check valve at the lower end of the vertical conductor drilling.

Design of Fig. 3 is open to the criticism that the fuel oil is deposited on the atomizing plates on one side only. If the oil is not thin and fluid and the engine speed is too great the oil will not have time, between injection periods, to distribute itself completely around the plate. The injection air will then strike the oil on one side of the plate only while on the side of the plate opposite the delivery point of the oil it will have a free passage unobstructed by oil. This allows the injection air to reach the combustion chamber in advance of the fuel and as explained previously this will chill the cylinder air charge sufficiently to cause misfiring at times.

This objectionable feature has been overcome in more recent valve design as will be shown in the second installment of this series.

Quarter Turn Rubber Belt

By N. G. Near

RECENTLY a prominent dealer in rubber goods wrote me regarding the length of a quarter turn rubber belt as follows:

"To settle an argument, I would like to have your opinion on the following:

"A customer orders a rubber belt made endless, 20 in. wide, 8-ply thick, 53 ft. 7 in. long net.

"He remarked on the order that the belt was to be run on a quarter turn.

"If 53 ft. 7 in. represents the steel tape measure around the pulleys, how much longer should the belt be made to take care of the quarter turn?

"Would there be any difference in length and if so, how much between a belt 8 in. wide and a belt 16 in. wide, or a belt 24 in. wide, assuming that the width of the pulley would accommodate the wider belt, and the diameter of pulleys and center to center dimensions remain fixed? In other words, a steel tape around the pulleys would show 53 ft. 7 in. Please advise."

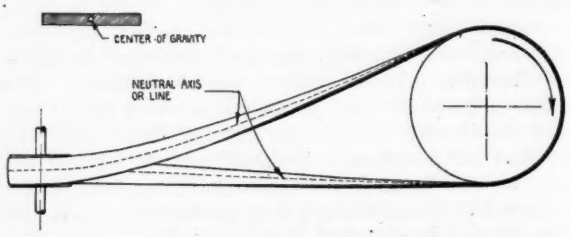
The following is my reply:

"I would not make the belt any longer or shorter on account of the quarter turn, but it might be well first to write the customer and ask him if he made the measurements along the exact central line which I have indicated on the enclosed sketch by means of the dotted line.

"In making measurements around the pulleys, the tape should follow the neutral axis or line as closely as possible, because, as you know, at the point where the belt leaves one of the pulleys as indicated in my sketch, one edge of the belt is in tension and the other in compression whereas the central line is neutral.

"To make the measurement absolutely accurate, the pulleys should be built up an amount equal to one-half the thickness of the belt. This is because the theoretical length of the belt is equal to the length of the line through the center of gravity of the section of the belt measured along the neutral axis. I have made a cross sectional view of the belt and have indicated the center of gravity. The distance this center of gravity moves through in going completely around the pulleys once would be the correct length of the belt.

"Of course, the slight difference in length caused by half the thickness of the belt would probably be neglected because a steel tape measurement around the pulleys would



LENGTH OF QUARTER TURN BELT IS MEASURED ALONG THE NEUTRAL AXIS

make the actual belt slightly shorter than if the pulleys were built up and you will no doubt want to make it slightly shorter anyway to take care of stretch.

"If you would rather not write the customer, my recommendation would be to go ahead and make the belt the same length as for any other drive."

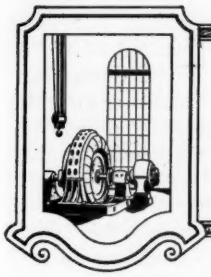
What About the C. E.

By James E. Noble

I WONDER how many chief engineer readers of Power Plant Engineering receive mail addressed to John Doe, C. E. I have received advertising literature, describing power plant equipment, so addressed several times. The manufacturers should realize that the sensible chief engineer feels insulted, that he is being made a joke, when addressed in this way. A person has no right to accept or adopt this title of C. E., which is the recognized abbreviation for the title civil engineer, unless he obtained it in the regular academical manner. It is practically in the same class as the degree of M. E., E. E., M. D., B. A., etc.

In Ontario, Canada, where I live, the degree of C. E. is scholastic, academic, not commercial, as chief engineer is. Some American manufacturers or their mailing clerks appear to be unaware of this fact. A person in Ontario has no more right to assume the title of C. E., unless he obtained it in the prescribed way, than he would have to place Ph.D. after his name because he happened to know a little philosophy.

When a chief engineer signs his name as John Doe, C. E., he is making a joke of himself for the sensible folk to laugh at. Study, observation and experience may have made him better qualified as a civil engineer than are many of those who are entitled to use the letters, but that is not to be taken as an excuse for using them. A man holding no engineer's certificate may be a better all around engineer than many men holding first class papers, but that does not entitle him to accept service as a first class certified man. If you are just John Doe, chief engineer, sign your name that way, and the sensible man and the genuine C. E. will respect you as a first class chief engineer in the commercial or industrial meaning of the term.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Operation of A. C. Generating Apparatus---III

THE THREE-PHASE ALTERNATOR; PRINCIPLES INVOLVED IN ITS CONSTRUCTION AND OPERATION. BY V. E. JOHNSON

WE HAVE ALREADY stated, in the previous article, that the "power factor" is the cosine of the angle between the voltage and current in an a. c. circuit and have shown curves illustrating this angle of displacement. Before proceeding further, brief consideration must be given to the actual conditions that produce this phase displacement.

In a circuit which has no magnetic effect, and which does not act as a condenser, the voltage and current are in phase, and the power factor is unity. Examples of circuits having approximately 100 per cent power factor, are incandescent lamps, and ordinary electrical heating devices such as irons and toasters. In these the current comes to its maximum value at the same instant as the voltage and may be thought of as having no "electrical inertia." This expression is really a misnomer, but it affords a mechanical picture that somewhat simplifies the discussion.

EFFECT OF INDUCTANCE

Circuits which have magnetic effect—such as magnet coils, generator coils, or transformer coils, do not permit the current to increase and decrease in unison with the voltage, but have inherent in them this property of inductance or electrical inertia which delays the current. This is due to the fact that they have set up in them self-generated voltages due to the varying magnetic flux strength in them—and this self-generated or self-induced voltage combines with the impressed voltage, and produces instantaneous current values which do not coincide with the voltage waves of the supply circuit.

If a magnetic coil had no losses of any kind in its conductors or core, that is to say, if no energy were required to magnetize it, then the current flowing through its windings would be 90 deg. out of phase with the voltage across its terminals and would be behind it. This can be partially deduced mathematically as follows:

We have seen that

$$\text{Kw} = \frac{\text{V} \times \text{A} \times \text{P.F.}}{1000}$$

If the kilowatt input into a given coil were zero, it is evident that one of the three constants on the right hand side of the equator would have to be zero. But inasmuch as V and A, are not zero but are measured by instruments, it follows that the third factor, namely P.F. must be. If the power factor is zero—the angular displacement, is, as we have previously seen 90 deg.

We know that alternating current will pass through a condenser. In this case, if there were no losses of any kind, the power factor would also be zero, and the current displaced from the voltage by 90 deg. However, under these conditions the current would be ahead of the voltage.

Inasmuch as no circuit can be entirely free from losses, neither of the two above conditions could be attained in practice, but they could be closely approximated.

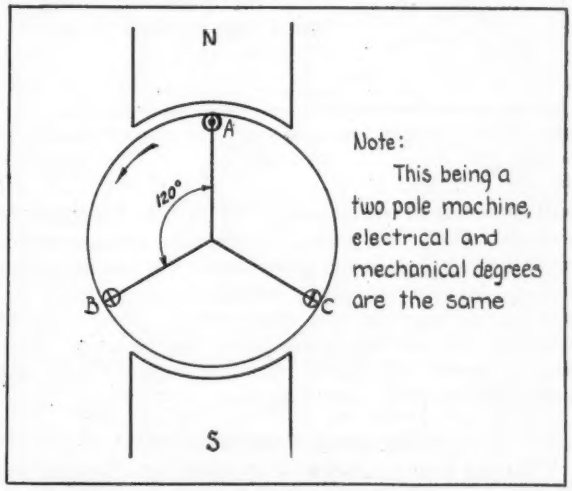


FIG. 1. DIRECTION OF VOLTAGE INDUCED IN A TWO-POLE GENERATOR

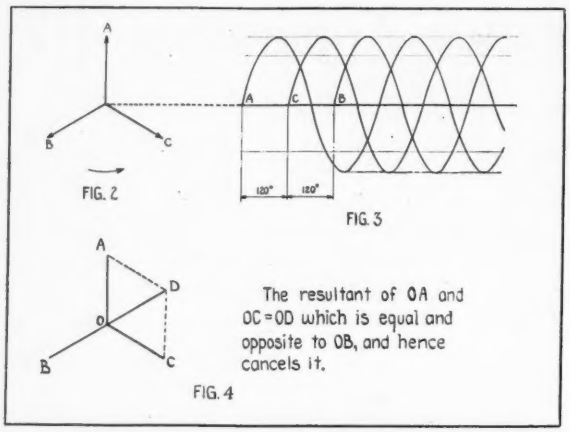
We present herewith a tabulation that shows at a glance the power factor characteristics of circuits such as are ordinarily met with in practice. The expression "leading power factor," means that the current is ahead of the voltage, while "lagging power factor," indicates that the opposite is true.

Per cent P.F.	Characteristic of circuit	Example
100	Non-inductive resistance	Incandescent lamps
80 leading	Combined resistance and capacity	Long transmission lines
0 leading	Condensers	Static or synchronous condensers
80 lagging	Combined resistance and induction	Motors
0 lagging	Inductive	Choke coils

The power factor can, of course, vary from zero to 100 per cent leading or lagging, depending upon the relative

value of the resistance, inductance, and capacity in the circuit. The tabulation shows only 80 per cent—this having been taken at random, as representing an intermediate value.

If a generator supplies current to a number of circuits, the power factor of its output is determined by the nature of the load in these circuits. Thus if the load is largely incandescent lighting the angle of lag will be small. If the generator be used to charge a long transmission line that is open circuit at the distant end, the power factor



FIGS. 2—4. VECTOR RELATIONS OF VOLTAGES OF MACHINES IN FIG. 1

will approximate zero leading. If to this line there be connected some loads containing magnetic coils, as motors or transformers, then the power factor will become higher and if a balance between the leading charging current and the lagging magnetic (or magnetizing) current can be obtained, the resultant power factor may be unity. Similarly a circuit with many motors or magnetic coils may approach zero power factor lagging.

Practical Consideration

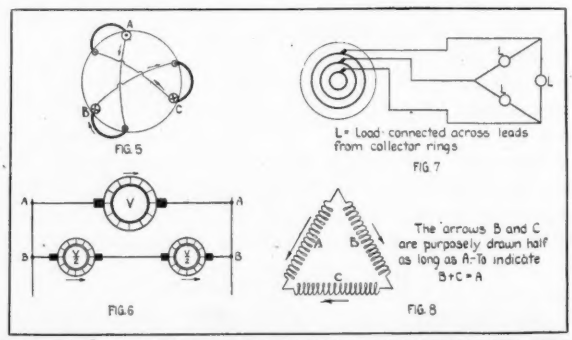
We can now proceed to a discussion of electrical machinery and so apply the principles above. An armature, whether of the rotating type, or of the stationary type has 360 mechanical degrees in its circumference, just as has any circle. If it has 60 poles, each pole space occupies 6 deg., and a pair of poles 12 deg. A conductor passing these two poles passes through two alternations or one cycle—this being equal to 360 electrical degrees. In other words, on a 60-pole machine, 12 mechanical degrees equals 360 electrical degrees. It follows, therefore, that if two machines have for example 60 poles and are displaced 120 deg. electrically, this would mean a mechanical displacement of only 4 deg. If the machines were slow speed, and had a greater number of poles, say 120, the mechanical displacement would be only 2 deg.

In applying the foregoing discussion to a concrete example of an alternator, it is simplest to use a two-pole revolving armature machine. In a two-pole machine there is one cycle per revolution, so that the 360 deg. into which a cycle is divided, corresponds to the 360 deg. into which the "circle" of the armature is divided. In other words, in this case the mechanical and electrical degrees coincide.

Figure 1 shows a two-pole machine, with an armature having three conductors on its surface. No interconnections are shown, as our primary discussion will cover only the action of the flux on the individual coil sides. "A" is under a north pole, and has set up in it a voltage "up" through the paper, as indicated by the dotted circle which represents the point of an ascending arrow. "B" and "C" are adjacent to a south pole, and have generated in them a voltage in a direction "down" through the paper, as indicated by the symbol shown which represents the tail of a descending arrow. If the field distribution is uniform across the entire armature, the voltage set up in A will be equal to twice the voltage in B or C.

Furthermore it is evident that A, B and C will generate their maximum voltages of similar polarity one-third of a revolution apart, or expressed differently, A, B and C are displaced 120 deg. from each other. That being the case, the vectors can be represented by Fig. 2 and the waves generated by Fig. 3. The resultant of the three is obtained in the usual manner, which from Fig. 4 is seen to be zero. This is borne out in Fig. 3 if the instantaneous values at various parts of the three waves are added.

It is evident, there, that the three conductors can be connected in a closed loop without having any current



FIGS. 5—8. DIAGRAMS ILLUSTRATING PRINCIPLES AND CONNECTIONS OF THREE-PHASE ALTERNATORS

circulate. This is shown in Fig. 5, where in addition, the return half of each coil is drawn in. In order to keep the relations of the coils clear, one half is drawn heavier than the other. The connections on the bottom of the armature are shown inside of the circle, while the top connections are shown on the outside. The dots and crosses in conductors show the direction of the general voltages, as in Fig. 1. At the instant represented A has the highest voltage—being at the maximum point. Tracing the connections through will show that the voltage on it is opposed by the combined voltages of B and C. The effect is that shown in Fig. 6 where an analogous connection of three direct-current machines is given. The voltage A-A being equal to the resultant voltage of the two smaller machines, B-B, no current will flow.

In the alternator in Fig. 1 the conductors sweep by the poles in rapid succession, and the voltage generated in each varies from maximum positive, to maximum negative. The phase relation between the three coils remains unchanged and as a result the sum of the three voltages is always zero. Thus at an instant when A is zero, B and C are equal and opposite, while later when B is maximum positive, A and C are one half maximum negative.

So far consideration has been given to instantaneous values only. The effective value, as measured on a voltmeter would remain constant and three voltmeters con-

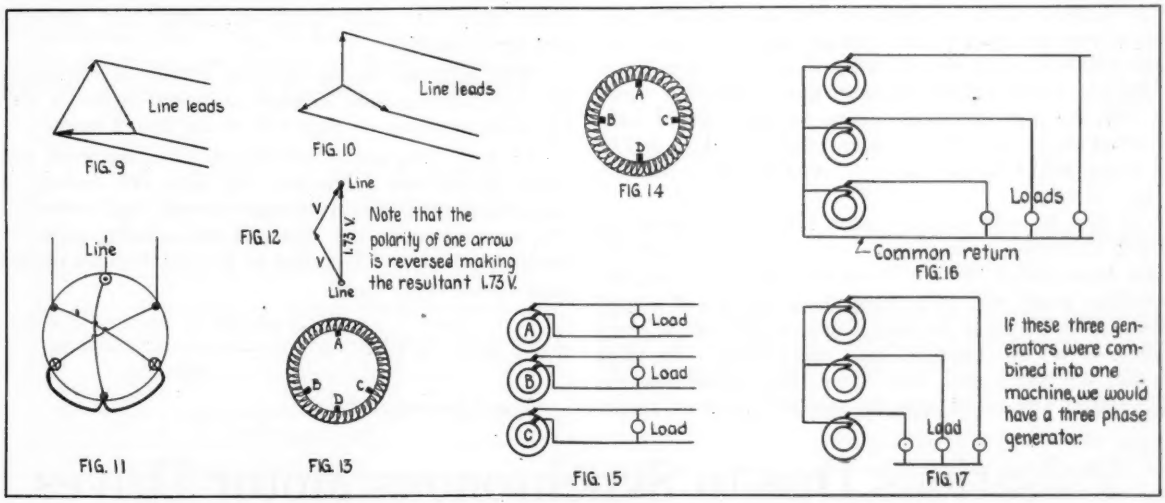
nected from A to B, from B to C and from C to A, would read equal continuous values. If these points were connected to three slip rings, load could be connected across any pair, or across all of them, as shown in Fig. 7. The voltage across any pair of the three leads would be constant, and would be 120 deg. out of phase with the voltage across either of the other two pairs.

Here then, we have the meaning of the word "phase" as used in the expression "poly"-phase generators. The machine in Fig. 1 is a three-phase alternator generating its voltage in the separate positions, and also supplying current in three different parts as shown. In an actual machine there would, of course, be more than one coil per pole, and each coil would consist of more than one turn. This would not in any way affect the validity of the foregoing discussion.

This resultant is equal to 1.73 times the phase voltage. Figure 12 shows vectorially how the phase voltages combine to form the potential impressed on one pair of line wires. Therefore, using the same magnetic strength, and the same winding, a star connection will give a higher voltage than will a delta connection.

Referring again to Fig. 9, it can be seen that the current which flows into any line wire is supplied by two generator phases. These phase currents combine at a displacement of 120 deg. As a result, the effective value of the line current is 1.73 times the effective current in either of the adjacent phases. In a star connection it is evident that the line current comes through its corresponding phase winding alone.

It appears from this that a machine connected in delta has a higher current capacity than one connected in star.



FIGS. 9—17. DIAGRAMS SHOWING CONNECTIONS OF POLYPHASE A. C. GENERATING APPARATUS

The connection between coils in Fig. 5 can be shown diagrammatically as in Fig. 8. At the instant in which the coil A passes under the center of the north pole, the voltage relations are as indicated by the arrows—assuming that the length of the arrows is proportioned to the instantaneous voltages. This is known as a delta connection, the name being derived from its resemblance to the Greek letter delta.

There is another connection of the coils in a three-phase machine known as star or Y. In Fig. 5 it is seen that the winding progresses around the armature in much the same manner as twine is wound on a ball, and that the end of one phase connects to the beginning of the next. This is expressed diagrammatically in Fig. 9 where the head and tail of the arrows indicate the start and finish of each phase winding. If then instead of this, a connection as in Fig. 10 is used, joining together all of the "starts," and connecting the "finishes" to the collector rings, the arrangement is named "Star." Figure 11 shows the connection for a two-pole machine having one coil per phase per pole.

In a delta connection it is evident that the line voltage, or voltage across the collector rings is equal to the voltage across any one of the phase windings or "phases" as they are usually called.

In a Y or star connection, the line voltage is the resultant of two-phase voltages 120 deg. apart in phase.

For high voltages then—the star connection would in general be preferable, while for high currents the delta connection would have the advantage.

In Fig. 13 is shown a diagram similar to that in Fig. 5 except that a ring winding is used. This simplifies the schematic connections and does not in any way affect the validity of the discussion. The conductors on the inside of the ring are inactive, and may be considered merely as end connections between the turns which lie on the exterior circumference.

If collector rings be connected to the points A, B and C, three-phase alternating current will be supplied to the mains, as previously described. If, however, only two collector rings be used, and they are connected to two diametrically opposite points as A and D, single-phase current will be taken from the machine.

If four collector rings be used, connected to four points as A, B, C and D in Fig. 14 then two-phase current would be supplied, each pair of rings feeding one phase. If in distributing this current 4 wires are used, the system is referred to as "two-phase, four-wire." If two wires are made "common"—and one wire so eliminated, the designation is "two-phase, three-wire."

There are a considerable number of two-phase systems in use in this country, but the great majority of installations are three-phase. Furthermore, few new developments utilize the former while, on the other hand, a number of

power systems which were originally installed as two-phase are being changed over to the latter.

This greater use of three-phase systems justifies us in discussing its phase relations in somewhat more detail. We have seen how three-phase voltages are generated by tapping a continuous winding at three equi-angular points, the angles being measured in electrical degrees. There is another way to look at this phenomenon—and a brief description may still further clarify it.

To an engineer familiar with direct current, a single-phase generator presents no difficulties. It has two wires as has a d. c. generator, and has no confusing "phase relations" entering in, as have the poly-phase alternators. Consider now three single-phase machines coupled to each other, and a pair of leads coming out from each. We would have three single-phase voltages generated simultaneously and three single-phase systems could be supplied with current. This is shown in Fig. 15. If these machines were so keyed to the common shaft that the voltages generated in them did not rise and fall simultaneously, but were one-third of a cycle apart, then they would be 120 deg. out of phase. This, however, would have no effect on the individual system supplied by A, B and C, as there would be no electrical interconnection of any kind.

If now, in order to save copper, the return currents be passed through a common conductor as in Fig. 6 and the loads be connected between it and the mains as shown, the condition would still be unchanged—as the use of a common return would in no wise interfere with the separate operation of the machines and their loads. In other words, we would still have three single-phase systems. The return wire would carry the sum of these three single-phase currents. If the loads were equal, the relation would be that in Fig. 3 and Fig. 4 except that we are dealing with currents instead of voltages. The three single-phase currents would give a resultant of zero—and an ammeter in the common return would give no indication. Obviously, if the return wire carries no current, it might as well be omitted as in Fig. 17. Here we have then a star connected load fed from a star connected set of generators, and the conditions are exactly the same as previously described.

Sometimes a three-phase star connected generator has the common or Y point brought out to the connection board. Such a machine would be called a three-phase four-wire generator, in contradistinction to one having only three leads, and hence called a three-phase, three-wire generator. This fourth wire is sometimes connected to the fourth wire of a 3-phase, four-wire circuit, and at other times is either grounded directly or grounded through resistance.

With reference to the previous articles of this series, our attention has been directed to several errors in Part II which appeared on page 183 of the Feb. 1 issue.

On page 185, second column, 9th line, the word voltmeter should read wattmeter. On page 186, second column, 7th line, the word deviation should read derivation. The word waves, in the 13th line, 2nd column, page 186, should read wires. The next to the last formula on this page should read

$$3\ \phi\ 4 \text{ wire. } Kw = \frac{\text{volts to neutral} \times \text{amp.} \times \text{P.F} \times 3}{1000}$$

The 3 was omitted.

Pulsations Due to Synchronous Motor Drives

USE OF SYNCHRONOUS MOTORS FOR DRIVING COMPRESSORS MAY CAUSE SEVERE PULSATIONS IN POWER ON THE LINE SUPPLYING THE MOTORS. BY QUENTIN GRAHAM

DUE TO THE recent ruling of the Electric Power Club concerning the pulsations of power which result from the use of synchronous motors with reciprocating compressors, or similar machinery, there has been a considerable amount of interest, or rather renewed interest, in the effect of such pulsations. For a long time it has been known that the combination of a synchronous motor and a reciprocating compressor results in a pulsation in the line current, and that the magnitude of the pulsation is dependent upon the charactertistics of both machines and upon the total flywheel effect of the unit. It has been known also that large pulsations in current may cause corresponding variations in the supply voltage, and that this may set up oscillations in other motors or cause flickering of lights. Previous to the action of the Power Club, there was no standard to which the various manufacturers of motors and compressors could work in limiting the amount of pulsation, and the natural consequence was a wide variation in results. The new ruling was an attempt to fix a standard which could be followed in most cases and which in other cases would serve as a basis for a similar agreement between those concerned. The rule is as follows:

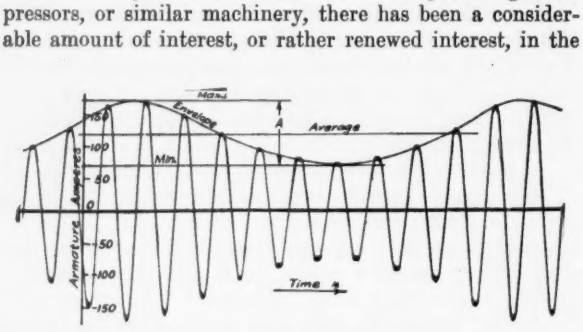


FIG. 1. OSCILLOGRAM SHOWING PULSATIONS IN ARMATURE CURRENT OF SYNCHRONOUS MOTOR DRIVING A COMPRESSOR

When the driven load, such as that of reciprocating type pumps, compressors, etc., requires a variable torque during each revolution, the combined installation shall have sufficient inertia in its rotating parts to limit the variations in motor armature current to a value not exceeding 56 per cent of full load current. The basis of determining this variation shall be by oscillograph measurement and not by ammeter readings. A line shall be drawn on the oscillogram through the consecutive peaks of the current wave. This line is the envelope of the current wave. The variation is the difference between the maximum and minimum ordinates of this envelope. This variation shall not exceed 66 per cent of the maximum value of the rated full load current of the motor—the maximum value of the motor

armature current to be assumed as 1.41 times the rated full load current.

Figure 1 illustrates the meaning of this rule. This shows an oscillograph record of the line current in an actual installation. The difference between the maximum and minimum current, indicated by A should be not greater than 66 per cent of the maximum value of the full load current, indicated by the line drawn through the average peak current. Referring to the case illustrated in Fig. 1, the motor rating was 400 hp. three phase, 25 cycles, 2200 v., 150 r.p.m. The variation is

$$\frac{170 - 70}{120} \times 100 = 83 \text{ per cent}$$

of the maximum value of the full-load current, assuming the latter to be equal to the average peak value of the current. This variation is 17 per cent in excess of the 66 per cent limit specified by the Electric Power Club. In the case of a motor having an actual load somewhat less than its rated load, the average line drawn on the oscillogram would not be used as the basis of figuring the per

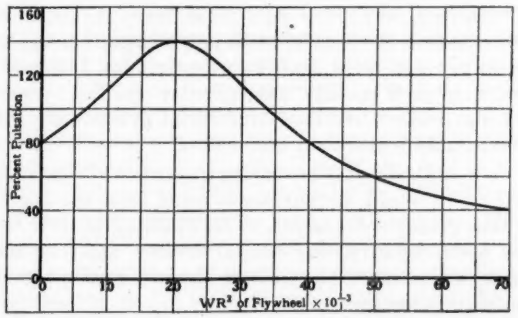


FIG. 2. VARIATION OF PULSATION WITH FLYWHEEL EFFECT

cent variation since it would not represent the rated load current.

Causes of Pulsation

In compressor practice, the torque required to drive the machine varies during each revolution so that the motor is continually changing its phase position, forward and backward, in order to supply the required torque. The addition of flywheel effect to the unit changes the amount of oscillation of the rotor, since part of the variations in torque are taken up in accelerating and retarding the mass of the flywheel. The resultant change in phase position determines the magnitude of the variation in current drawn from the line.

It is interesting to note that the effect of additional flywheel effect or WR^2 is not in direct proportion to the amount of WR^2 added. If this were so, the problem would be fairly simple and the remedy for any case of excessive pulsation would always be the same. It so happens, however, that there may be two widely different values of WR^2 which give equal amounts of pulsation, but with a WR^2 somewhere between these two the resulting pulsation will be greatly increased. The curve in Fig. 2 shows per cent pulsation plotted against WR^2 for a typical case. The usual method of considering this problem is to determine the natural frequency of oscillation of the unit, which is a function of the WR^2, and to compare this with the frequency of the variations in compressor torque. As the two frequencies approach one another, a condition of resonance is reached, and the oscillations attain a maximum which is limited only by the damping effect.

It is the complexity of this problem that has been responsible for a great deal of misunderstanding and for operating results which have the appearance of being inconsistent. For example, the fact that similar units may have equal values of pulsation with entirely different flywheels,

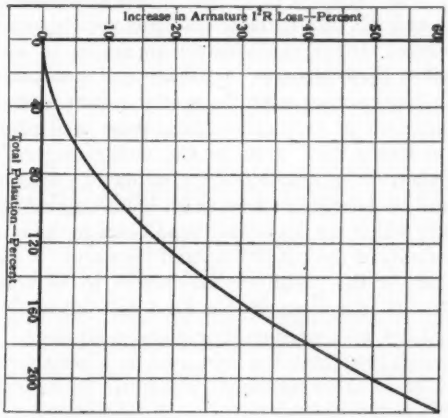


FIG. 3. EFFECT OF PULSATIONS OF THE ARMATURE CURRENT ON THE ARMATURE COPPER LOSS

and that a case of excessive pulsation may possibly be improved by either an increase or a decrease of WR^2 are facts not always readily understood.

Effects of Pulsation

Effects of pulsating current and the reasons for establishing limits may be discussed from the standpoint of the supply line of the motor itself. If violent fluctuations are

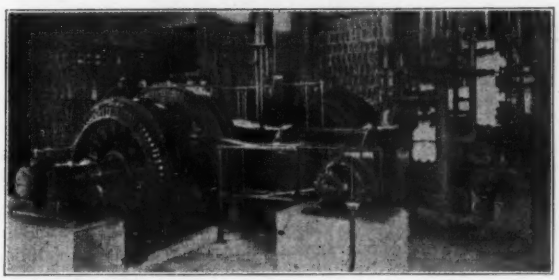


FIG. 4. TWO 125 HP. ENGINE TYPE SYNCHRONOUS MOTORS DRIVING AMMONIA COMPRESSORS

permitted, the motor performance may be affected in several ways. The motor may swing far enough to fall out of step and make operation impossible; or it may be so sensitive that any additional disturbance will cause it to pull out. Even though the machine appears to operate satisfactorily, the continuance of varying forces may result eventually in a breakdown in the windings.

Resultant I^2R loss in the armature winding and the consequent heating are greater with large pulsations in current than with small pulsations for the same average load. The curve in Fig. 3 shows the relation between armature copper loss and per cent pulsation. This curve is based on the case in which the envelope of the current wave is also a sine curve. This covers the most usual case,

although the envelope may be a curve containing harmonics which would result in a loss differing from that shown in Fig. 3. It will be noted that a pulsation of 66 per cent gives a loss which is only about 5 per cent greater than would occur with a steady load.

Installations in which a synchronous motor-driven compressor forms a large part of the total plant load are quite likely to experience trouble if the motor current fluctuates widely. The variation in current causes a variable drop in the line and the transformers and thus results in a pulsating voltage. Other synchronous apparatus in the plant may follow these changes in voltage and produce oscillations in synchronism with those of the compressor motor. If a condition of resonance exists, these oscillations may be more severe than those in the motor originating the disturbance. The amount of pulsation of motor current that can be tolerated varies with different installations. The ratio which the compressor load bears to the total load, the constants of the power line, and the nature of the other apparatus in the plant are all factors to be taken into account. It is evident that a fixed rule allowing 66 per cent will not give satisfactory results in all cases. On the other hand, this limit has been used as a basis for a large number of actual installations which are entirely satisfactory. It is low enough to insure an absence of trouble in the motor itself and to prevent high additional loss in the windings, and appears to be conservative enough to prevent trouble from other sources in most plants. Aside from the actual limit established, the ruling is valuable in that the need for some such agreement is brought to the attention of engineers responsible for compressor installations, and a basis is formed upon which special agreements for particular cases may be made.—Electric Journal.

Research, the Mother of Industry

PROGRESS DURING THE LIFETIME OF ONE MAN AND THE PART WHICH RESEARCH HAS PLAYED. FROM AN ADDRESS BY ARTHUR D. LITTLE BEFORE THE DIVISION OF ENGINEERING OF THE NATIONAL RESEARCH COUNCIL

SO RAPID are the developments in industry that it is difficult to follow them or to visualize what is making possible the great strides in materials available and processes used. To show these things and the part which research plays was the object of the meeting which was addressed by Wm. H. Bassett, technical superintendent and metallurgist of the American Brass Co., Charles F. Kettering, president of the General Motors Research Corp., A. D. Little of Arthur D. Little, Inc., W. R. Whitney, director of the research laboratory of the General Electric Co.

In his address, Mr. Little gave striking details of the advances which had taken place during his life, yet he is by no means an old man. He spoke of the first telephone, the first arc light, the first exhibition of the talking machine, which he saw as a boy. The time is but short since Herz announced the discovery of the waves which bear his name and which are the basis of the wireless telegraph and radiotelephony.

Mr. Little called attention especially to the results of chemical research. "When I began the study of chemistry, we were taught that certain gases were permanent because they had not been liquefied. Almost before I learned the lesson, Pictet and Cailletet had liquefied oxygen, while liquid air has now become a commonplace of the laboratory and the raw material for great industries.

"I was also taught that atmospheric air contained only oxygen, nitrogen, aqueous vapor and a small proportion of carbon dioxide. Lord Rayleigh and Sir William Ramsey were not so credulous and demonstrated the existence in air of five hitherto unknown gases,—Argon, Helium, Neon, Krypton and Xenon. Even their names carry interesting suggestion. Argon, the lazy one because it forms no compounds; helium, whose existence was first revealed in the Sun by the spectroscope; neon, the new one; krypton, the hidden one; xenon, the stranger. But already argon has been put to work in the bulbs of incandescent lamps; helium has taken the place of hydrogen for inflating airships; neon tubes flash advertisements from store windows and assist in locating automobile engine troubles."

To research more directly connected with industry are due the aluminum process, carborundum, calcium carbide, the Diesel engine, artificial silk, new processes for making bleaching powder and alkalis, synthetic dyes and radium with its numerous compounds.

"Research, which has paid these heavy dividends and many others in one decade, needs only recognition and support to pay still more heavily in the future. Instruments of research grow steadily more effective and the means for reducing research results to industrial practice are today incomparably better than ever before.

"I would apologize for having given this review so personal a tone were I not anxious to bring home the fact that all these great developments, so far reaching in their influence upon industry, our mental outlook and our social structure have taken place within the easy recollection of a man still on the job.

"Three fundamental factors are involved in industry; capital, labor and the creative mind. The last may function either along the lines of organization and management or of research. Industry is constantly pushing its outposts forward into new territory wrested from the unknown by its advance guard, science. Science is merely information so classified and organized as to be used effectively and information, to quote General Phil Sheridan, is 'the great essential of success.'"

Revolutionary changes are soon to come in the preparation and use of fuel. Powdered coal is already established and much progress has been made in low-temperature carbonization with recovery of valuable chemicals and the production of artificial anthracite. Systems for the complete gasification of coal have been developed and there are serious proposals for great gas works at the mines with distribution of industrial gas through high-pressure mains.

Steam pressures have reached 500 lb. and 1200 and 1500 lb. are being tried. This brings problems in the behavior and strength of steel at high temperatures in contact with water and gases, which can be solved only by intensive research. For the gas turbine, which seems to be nearing a solution, more research is required.

"In the past, our prosperity has been based, largely, on superabundant raw materials and cheap land. Today our civilization has developed so that we can hope to maintain our position only through the assistance which science can afford. The laboratory has become a prime mover for the machinery of civilization and there is a direct obligation upon industry to support, with the generosity of an enlightened self-interest, its Mother, Research."

Printed Instructions and Their Preparation

MOST engineers are familiar with the improvements which are constantly being made in the design and construction of power plant machinery. Although the layman may not know just how these betterments are brought about, he can visualize large research laboratories with specialized engineers experimenting with new ideas. He can also picture a large scrap pile near the laboratory which is the "Happy Hunting Ground" of unsuccessful experiments.

But out of all this effort and material there arises one improvement after another, so that this scrap pile is really the index to progress. It marks the years of effort from which we have the present machinery—such, for example, as a compressor, which is a simple, efficient machine, easy to understand and easy to operate. For the true designer is he who can lay out a machine which does the work with maximum economy and at the same time is free from complicated mechanisms.

Few of us, however, even he whose duty it is to operate a compressor, realize just how much effort is spent in preparing instruction books, cards or part lists, so that the machine does not arrive unintroduced. For what could be more confusing and discouraging than the arrival of a car load of strange crates, housing still stranger parts, without any information of what it is all about and how to put it into practical use and keep it running to best advantage?

It is true that instruction books are not new. We expect one with every piece of equipment in the power plant just as we do with an automobile. Sometimes we look at it; sometimes we don't. Such carelessness is probably due to the memory of some former instruction book which seemed to contain only information which we did not need or want. We did not realize that even as machines are being built better so are the instruction books improving. Perhaps this would never have been appreciated had every machine performed without trouble.

Manufacturing concerns who wish to have their products give the best of service and satisfaction spend many dollars and hours in improving their instruction books, part lists, and other printed material classed under the general heading of service literature. They have put this ahead of selling publicity and advertising with the result that each new instruction book is an improvement—something to make it easier for the man who runs the machine and thus better for the results which this man secures for his employer.

Ingersoll-Rand Co., for example, has adopted the policy of asking customers for information and suggestions. The expert erecting engineers and service men employed by the company are asked to answer a group of questions and tell just how each one erects a machine on the job. The special tricks of each erector gained by his years of field experiences are carefully collected and preserved and from all this mass of miscellaneous material is prepared the instruction book.

Photos are posed in the shop so that the various parts may be clearly and exactly shown. Take a crosshead, for instance; all the parts which make up the complete crosshead are grouped and a photograph taken of the unassembled crosshead. Then the assembly is photographed; next a picture of the crosshead in place in its guides in the compressor frame. Often for clarity each part is lettered so that it is easy to follow the written description of any part or operation. In fact, the newer instruction books have more engravings or cuts than are found in the bulletin, catalog or other selling literature.

Such a book is not only a "how and why and wherefore" for the particular type of compressor but it contains valuable information about piping, receivers, aftercoolers, etc., all of which enter into the overall efficiency of the compressed air plant.

Thousands of dollars and even human lives can be saved by following what the manufacturer knows to be best for his machine. If an instruction book is lost send for another; if it is not clear, ask a representative of the manufacturer to help you out.

Long Range Water Level Indicator

By C. W. Geiger

IN THE ACCOMPANYING photograph is shown a reservoir water level indicator built by the engineer of the municipal water system of Hollywood, California, for the purpose of ascertaining the depth of water in the storage reservoir located in the foot hills some distance from the pumping station.

THIS DEVICE INDICATES THE DEPTH OF WATER IN STORAGE RESERVOIR

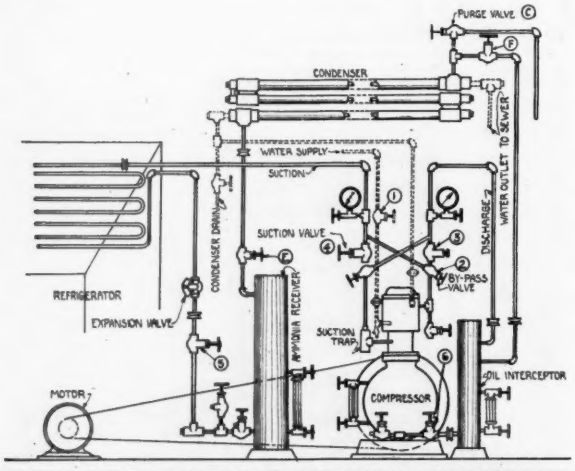
Previous to the construction of this indicator, it was necessary for the engineer to make one or two trips daily to the reservoir to ascertain the depth of water but now he can figure the exact amount of water in the reservoir by merely observing the indicator from the pumping station, thus eliminating the necessity of making the daily trips to the reservoir, which is extremely difficult of access.

This indicator consists of two posts about 12 ft. high, connected by horizontal slats. These slats are spaced so that each interval between them represents 10,000 gal. in the reservoir. The broad white board shown at A in the photo is connected by a vertical rod to a float in the reservoir. As the water rises and falls, the float causes the broad white board to rise and fall in front of the slats, thus enabling the engineer to calculate quickly the number of gallons of water in the reservoir.

Operating a Small Refrigerating Machine

INSTRUCTIONS TO BE FOLLOWED WHEN STARTING UP AND CLOSING DOWN A SMALL PLANT. BY H. NOONE*

IT IS ESSENTIAL to bear in mind when operating a refrigerating machine that the suction gage should never register over 30 lb. or below zero at any time when the machine is running. This suction pressure, or back pressure as it is often called, is controlled by the expansion valve. The expansion valve is sensitive, therefore care should be taken when regulating it, that the proper amount of ammonia is allowed to pass through. It is impossible to designate the exact back pressure at which each plant should be run, for the reason that climatic conditions, amount and temperature of condensing water and length of time that the machine has to run, will vary. The best rule to follow, however, is to operate with back pressure as low as possible still frosting through all the pipes, since the lower the back pressure, the colder is the ammonia gas and therefore a lower temperature is obtainable.



TYPICAL LAYOUT SHOWING THE ESSENTIAL EQUIPMENT FOR AN AMMONIA PLANT

If frost comes back to the cylinder on the machine to the extent that the discharge pipe gets cold, there is too much ammonia going through the expansion valve and the valve should be slightly closed. The expansion valve should not be closed when stopping the machine; instead stop valve No. 5 should be closed, thus not disturbing the setting of the expansion valve for the next day. In this way it is possible to find the exact setting for the expansion valve, so it will need no adjusting. If, however, the pressure should go down during the run of the machine, or fail to rise after starting the machine, it is because a little dirt has clogged up the small opening in the expansion valve. This is overcome by what is called flushing, which is accomplished by opening the expansion valve until the ammonia can be heard rushing through, then quickly bringing it back to the original setting.

*Refrigerating Engineer, Goetz Ice Machine Co.

WATER REQUIREMENTS FOR THE CONDENSER

In general, too much water cannot be used, this however does not mean that water should be wasted. The high or condensing pressure is controlled not only by the amount of condensing water that is used, but also by its temperature. So if condensing water is cold, it is not necessary to use as much as when the water is warm. Pressure should not go above 180 lb., unless the condensing water is above 75 deg. F., for the saving in water is offset by the extra power used. For average conditions 2 gal. of water are necessary per minute for each ton of refrigeration.

Each machine case is equipped with an oil gage which should show about one-half full. When the oil gets down case of the machine will in time wear out, it should be blown back from the oil interceptor as follows: slightly open valve No. 6, place the hand on the pipe between this valve and the machine and when ammonia appears, which is indicated by pipe getting cold, close valve No. 6. The oil can be seen to lower in the gage glass of the oil interceptor and rise in the gage glass on the machine by opening the valve at the top and bottom of the gage glasses. This should always be done when the machine is running, preferably about an hour after starting. As the oil in the case of the machine will in time wear out it should be changed about every six months and no other than special ice machine oil should be used because ordinary lubricating oil will freeze and gum up.

Air and foul gases will accumulate in the system at times, this being indicated by an unusually high pressure. To draw them off, fill a pail with water and submerge the purge pipe in it and then slightly open the purge valve C. The foul gas will bubble in the water and as soon as the ammonia starts to come it will be indicated by a cracking sound, similar to when steam is injected into cold water. The purge valve should be closed as soon as the ammonia starts to come. This operation should be done only after machine is stopped.

In cold weather the condenser and the machine water jacket should be drained to prevent freezing. To do this open water jacket drain cock and also remove the plugs on the end of the condenser. The condenser should be cleaned occasionally.

Once each year the pop valves on the machine should be reground, the safety valve in the discharge line cleaned and reset, the scale traps cleaned and new packing put in the stuffing-boxes of all valves. All valves, except the gage valves should be double seated, so that they can be packed without pumping out the system. The gage valves must be closed when packing them. Care should be taken when tightening the stuffing-box gland, to draw up evenly on the gland nuts. The outboard bearing should occasionally be washed out with gasoline. Gas inlet valve F and liquid outlet valve E on the condenser are to be closed only in case of a leak in the condenser, ammonia receiver or any part between the machine and the condenser.

To start the machine, fully open condenser water valve No. 1, fully open bypass valve No. 2, then turn flywheel

a few times in opposite direction to running and stop it at hardest point and then start machine. When machine is up to speed, open the discharge valve No. 3 one-eighth turn only, then quickly close bypass valve and fully open discharge valve. Open suction valve No. 4 one-quarter turn only and when suction gage pressure reaches 5 lb.. slowly open suction valve. Finally, fully open stop valve No. 5 and if necessary regulate the expansion valve. To stop the machine, close stop valve No. 5 and when the suction gage indicates zero but not below close suction valve No. 4. Stop the machine and then close discharge valve No. 3 but do not touch bypass valve No. 2. As a last step, the condenser water valve No. 1 may be closed.

Intermittent System of Refrigeration

DESCRIPTION OF A REFRIGERATION SYSTEM WHICH MAY BE OPERATED ON THE OFF-PEAK BOILER LOADS. BY W. F. SCHAPHORST

DURING recent years there has been considerable progress in refrigeration and as a result several new systems have sprung up. One of these systems, known as the "intermittent" system of refrigeration, seems adaptable wherever steam is to be had. This system has a number of features that may appeal to the average engineer. It is said by its makers that it is not a machine because it operates without motive power and without motion. There are no parts on it or in it that move, that reciprocate, or rotate, consequently it does not require lubrication.

One of the important advantages claimed for the intermittent system of refrigeration is that it can be operated by the use of steam just as in the absorption system. The latter system is already familiar to most engineers consequently it will not be described here. Another advantage claimed for the intermittent system is that the same steam boilers that are used for other purposes can be used for heating the generators. The boilers can be used during the night or at such time as the regular power load is light. Consequently it is claimed that it is seldom necessary to install a larger boiler upon the installation of the intermittent system.

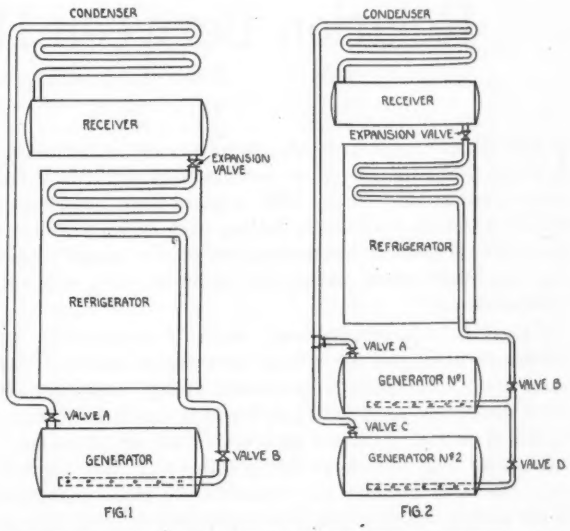
In Fig. 1 is shown a sketch which will assist in understanding this system. Beginning at the bottom is the generator which is really a boiler. Just as in the absorption system this generator is about ¾ full of a solution of water and ammonia, this solution being richer than is used in the absorption system. Heat may be applied to the generator either externally or internally. In steam power plants steam coils are generally used. These coils are placed inside the generator beneath the level of the liquid. These coils are not shown in the sketch because they are ordinary pipe coils similar to heating coils used in the absorption system.

LIQUID AMMONIA IS STORED IN A RECEIVER

At the top of the generator is a valve A and at the right hand side is another one designated as valve B. As soon as heat is supplied to the solution, ammonia gas is driven off and pressure is created just as in the absorption system. The gas passes upward through valve A (valve B being closed) and into the condenser shown at the top of the sketch. While passing into this condenser the ammonia condenses into liquid form and then continues down into the receiver as pure liquid ammonia. Here, however, is where this system of refrigeration differs from the regular absorption system. The expansion valve shown just below the receiver is not open while the ammonia is generated because the pipe leading from the expansion valve through the refrigerator goes right back into the generator and obviously it is impossible for gas to be forced out of the generator and then back into itself again.

Liquid in the generator contains more ammonia than in the absorption system. This is because it is desired to get as much ammonia as possible into the generator so that after the ammonia is all boiled out it will be in the receiver in liquid form. The receiver will therefore be nearly full of ammonia after the boiling process. This receiver is considerably larger than the receiver used in the absorption system because it must be large enough to hold all of the ammonia that was originally contained in the generator.

After the generating period is completed all of the ammonia will be found in the receiver and the liquid remaining in the generator is practically pure water.



SKETCHES SHOWING THE INTERMITTENT SYSTEM AS APPLIED TO BOTH PART TIME AND FULL TIME OPERATION

Valve A is then closed and by means of a set of cooling coils in the generator the liquid remaining in the generator is cooled so that it will absorb the gases after they come out of the refrigerator. The generator in this system is used both as a generator and as an absorber. In the absorption system we have both a generator and an absorber.

As soon as the liquid in the generator is sufficiently cooled valve B is opened wide and we are ready to refrigerate by opening the expansion valve and allowing the ammonia to pass from the receiver into the refrigerator as rapidly as may be necessary.

Sometimes in refrigerating work it is desirable to cool a large quantity of produce in a short time, say in an hour or two. Theoretically this could be done very nicely with this system by making the receiver large enough so that it will hold a sufficient amount of ammonia to take care of the entire cooling requirements during that period of time. Enough ammonia is injected into the liquid in the generator in the first place so that after it is all boiled over into the receiver it will suffice for an entire day's work. In

other words the ammonia in the receiver can be used up in one or two hours or in twenty-four hours just as the operator desires.

One of the important objections to this system is its high first cost which is generally considerably more than either the absorption system or the compression system. The generator is made entirely of plate steel and must be welded so that there will be absolutely no leakage. The coils inside the generator therefore are inaccessible for cleaning or replacing and the only way to renew them is to cut the generator in two, then renew the coils or clean them and after replacing them, weld the generator together again.

Still another objection to the intermittent system is that it is intermittent. Despite the claim that skilled attention is not needed, this system must be watched continually and skillful men are needed to operate it. Instances are on record where operators of compression refrigerating machinery were not skilled enough to run the intermittent system.

Adapting This System to Continuous Refrigeration

In large refrigerating plants a continuous system is needed and that is taken care of in this intermittent system by using more than one generator as shown in Fig. 2. By having two generators, No. 1 and No. 2, it becomes possible to absorb gas all the time, night and day and as long as gas is absorbed it is possible to refrigerate continuously.

Referring to Fig. 2, while the generator No. 1 is being heated and while gas is being driven off, generator No. 2 is absorbing. Valve A is therefore open and valve C is closed while valve B is closed and valve D is open. Cooling water is being run through generator No. 2 to keep it cool and steam is being passed through generator No. 1 to keep it hot. It surely looks simple enough and is possibly easier to understand than any other system of refrigeration.

Before selecting any system of refrigeration, much caution should be exercised by the engineer. Do not be too hasty. Consider all points, such as steam consumption, cooling water required, floor space required and the cost for installing added capacity.

Relation Between Heat and Temperature

Intensity of Heat or Temperature of a Body is its Ability to Transmit Heat to Other Bodies. It Does Not Measure the Quantity of Heat

CONFUSION often results from use of the terms heat and temperature. If we touch a body and it feels hot, we are accustomed to say that it has a high temperature and if we touch a cold body, we say that its temperature is low. These general terms can give only a rough idea of the condition which exists, for after all they are only comparative.

Heat is a form of energy which is produced by the vibratory motion of the minute particles of which all substances are assumed to be composed. These small particles, or molecules as they are called, are held together by mutual cohesion and at the same time are in a state of continual vibration. The more heat that is added to a body the more vigorous will become the vibration of these molecules. Heat energy can be perceived or measured only through the effects which it produces. The effect of heat on a body is to change its temperature, its volume or its state, that is, from solid to liquid or from liquid to gaseous. Measurement of the heat content of an object is the measurement of heat energy or heat content, the result being quantitative.

Temperature does not indicate the amount of heat which a substance contains but it does indicate the condition of the heat in the substance; that is, it describes the intensity of the heat, the result being qualitative. This point is illustrated by considering two vessels one of which contains 1 qt. of water at 80 deg. F. and the other containing 1 gal. of water at the same temperature. The temperature of the water in both vessels is the same, that is the quality of heat is the same in both cases. The quantity of heat energy stored in the gallon of water is much greater than that stored in the quart of water.

Another way in which this relation may be considered is that temperature may be thought of as the pressure of the heat in a body and as such it corresponds to the pressure indicated by a steam gage. The steam gage shows only the intensity of the pressure and not the quantity of steam in a boiler.

Unit for Expressing Heat Content

In order to express the heat content of a substance it has been necessary to establish a unit of quantity of heat. This unit is known as the British thermal unit (abbreviated B.t.u.) and it is defined as 1/180 of the

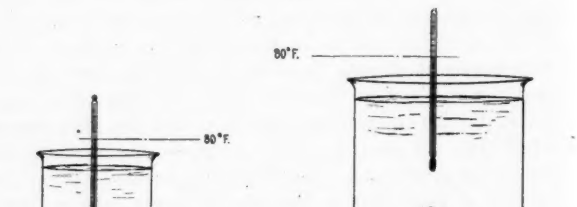


FIG. 1. HEAT CONTENT OF THE LARGE CONTAINER IS FOUR TIMES THAT OF THE SMALLER. THE TEMPERATURES ARE THE SAME

quantity of heat which will raise 1 lb. of pure water from the ice point (32 deg. F.) to the steam point (212 deg. F.) at atmospheric pressure. For extreme accuracy in defining the unit of heat it is necessary to specify the temperature of the water because the amount of heat necessary to raise the temperature of 1 lb. of water through 1 deg. varies slightly at different temperatures.

This variation is so slight, however, that for most practical problems the B.t.u. may be taken as the quantity of heat required to raise the temperature of 1 lb. of water 1 deg., without any reference being made to any particular temperature.

As a general rule, it is observed that the more heat or heat energy a body contains the higher its temperature will be. This observation does not hold true at or near the temperatures where a change of state takes place. An increase or decrease in heat content may occur when there

is a change of state taking place and at the same time the temperature may remain constant.

This is clearly shown in the evaporation of water. Here the change of state is from that of a liquid to a vapor. A definite quantity of heat is required to raise 1 lb. of water to the boiling point. We will assume that this water was originally at a temperature of 60 deg. F. and that it was raised to the boiling point at atmospheric pressure, which corresponds to a temperature of 212 deg. F. As heat was applied to this water the temperature increased in proportion to the heat added. When the boiling point was reached the temperature remained constant at 212 deg. F. although additional heat was applied which changed the water into steam or a vapor.

Measurement of the quality of heat or temperature is based upon an arbitrary scale. Regardless of the unit of measure which is to be established it is always advantageous to base the unit upon certain definite facts so that

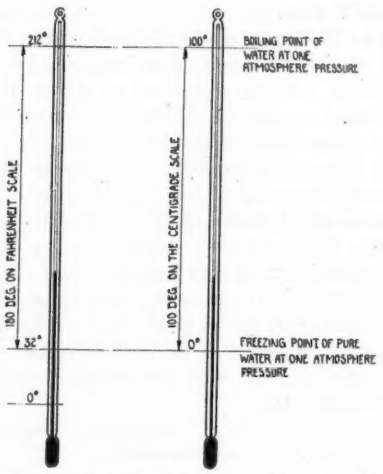


FIG. 2. SKETCH SHOWING COMPARISON OF THE FAHRENHEIT AND CENTIGRADE THERMOMETER SCALES

it may be readily checked for accuracy. It has been found that ice melts at a definite temperature, providing that the ice be formed from pure water and that fusion occurs at a pressure of one atmosphere. It is also known that the temperature of steam which comes from boiling water at a pressure of one atmosphere is a fixed quantity. These two fixed points are convenient to compare the relative temperature of any object or substance.

Thermometer Scales Now in Use

In English-speaking countries the Fahrenheit scale is in most common use. It is defined as 1/180 part of the rise in temperature from the ice-fusion point to the boiling point as previously outlined. The Fahrenheit zero is 32 deg. below the fusion or melting point of ice and the temperature of the boiling point is 212 deg. F., or 32 deg. plus 180 deg.

Another scale which is in common use in countries using the metric system is known as the Centigrade scale. The Centigrade degree is 1/100 part of the rise in temperature from the ice-point to the boiling point. The Centigrade zero is the ice-point and the temperature corresponding to the Centigrade boiling point is 100 deg.

In order to change from one scale reading to the other, we may use the following formulas:

To change from Fahrenheit to Centigrade—

$$C = \frac{5\ (F - 32)}{9} \qquad (1)$$

and to change from Centigrade to Fahrenheit—

$$F = \frac{9C}{5} + 32 \qquad (2)$$

As a practical example, we may assume that a Fahrenheit thermometer shows a temperature of 104 deg. and it is desired to find the corresponding temperature as indicated by the Centigrade scale. Substituting in formula (1) we have

$$C = \frac{5\ (104 - 32)}{9} = 40 \text{ deg. C.}$$

If our original reading of 104 deg. had been observed on a Centigrade scale and we wished to find the corresponding temperature on the Fahrenheit scale we would substitute in formula (2), so that

$$F = \frac{9 \times 104}{5} + 32 = 219.2 \text{ deg. F.}$$

It is customary to write Fahr. or simply F. for the word Fahrenheit and C. for the word Centigrade.

Development of hydroelectric energy in the Clarence River Valley, Northern New South Wales, is being started under the direction of Messrs. Armstrong, Whitworth & Co., Ltd., of London. The Nymboida hydroelectric scheme is the first of such dimensions in Northern New South Wales. The site of the power house is near the township of Nymboida, about 26 mi. from Grafton, where the stream attains its greatest volume. The estimate of the capital cost of the work is £100,000 and this sum has been borrowed on favorable terms by the Clarence county council from the Commonwealth Bank.

Current will be generated at the power house at 6000 v., and stepped up to 33,000 v., for transmission to South Grafton and Ulmarra. The transmission line is being constructed to these centers with a capacity of 1200 kw., and at both places substations will be erected, from which electricity will be distributed throughout the towns and adjoining districts.

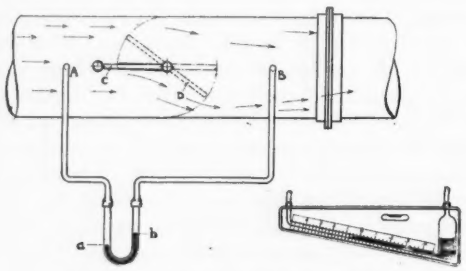
With 1600 hp. at the power station, the peak loads at the distributing centers will be 1420 hp., and the number of units that can be sold annually with 33 per cent load factor will be 3,090,000. That is the estimate of the power which will be avaliable for sale, and the County Council is now at work on the plans for distributing the power when the scheme has been completed, which has been set down as June or July, 1924.

Gasoline production in the United States attained a new high record in 1923, when 7,555,945,143 gal. were produced, states the Department of the Interior, through the Bureau of Mines. The figures represent an increase of 21.83 per cent over the 1922 gasoline output. While a record-breaking production of gasoline was being registered, the demand for the product attained an even greater percentage of increase. For the year 1923 the indicated domestic demand amounted to 6,685,035,280 gal. Exports were 871,116,614 gal., which added to domestic demand shows a total demand for the year amounting to 7,556,151,894 gal., an increase of 26.64 per cent over the total demand in 1922.

Does the Damper Work Properly?

ALTHOUGH THE damper in the flue is a commonplace part of the equipment of a plant, just as it is a minor part of the steam heating plant in the small home, it is nevertheless, a part that can cause a lot of trouble and annoyance unless it is securely fastened on the damper spindle in a position which corresponds to the position indicated by the handle outside the flue.

Dampers frequently get out of order by reason of the fact that the damper plate becomes loose on the spindle so that when the handle is turned outside to the position desired, the damper plate inside fails to move wholly or perhaps even partially with the handle. The position of the plate is therefore a matter of uncertainty and if



DOES THE DAMPER WORK PROPERLY?

the faulty operation of the damper is not so serious that attention is directed to it, it may continue indefinitely and other elements of the plant may be blamed for a lowered furnace capacity.

Trouble of this nature was easily located by a plant engineer not long ago, by the use of a simple device which he made. The device consisted of a couple of rubber tubes a few feet in length, two pieces of brass pipe (any other small pipe would have done as well), a glass tube which he bent into the form of a "U." The simple device is illustrated in the accompanying figure, together with the method of applying it to the flue.

In the center of the flue as at A, a hole is made sufficiently large to admit the small brass tube which is long enough to reach to the center of the flue. A similar hole is made at B at an equal distance from the damper spindle. This distance should be ample to permit the tube B to be beyond the influence of the currents which might be set up by the damper plate when in a horizontal position. Having inserted the tubes at A and B so as to reach to the center of the flue, a piece of rubber tubing is attached to each tube as indicated in the sketch. This tubing is then attached to the ends of the U tube. This tube should be sufficiently long to permit the fastening of the rubber tubing and also to provide length enough to fill the U with water to a height of say 3 in.

Having made the connections as indicated and filled the U tube with water, the device is ready for operation. Now, suppose the damper handle to be in the position as shown at C. The damper plate would normally be in the same plane and the flue would be open to its fullest extent.

Assuming this condition, the gases in the flue would flow on unobstructed and would exert equal pressures at A and B. There is thus no difference in the level of the water in the U tube.

In the particular case referred to, however, the damper was not in the correct position as indicated by the handle but assumed a position somewhat as shown at D. This position caused a pressure differential across the damper which was communicated to the U tube. The difference in the two columns denoted the difference in pressure due to the defective setting of the damper plate.

The business of crawling into a flue to ascertain the position of a damper plate is certainly not a desirable job even when necessary, though nobody would object to performing this duty if the necessity were apparent but when it is established that the damper plate needs attention, it remains only to repair it at the earliest opportunity and a man can enter the flue with the assurance that he is not on a "wild goose chase."

New York City. WILLIAM V. FITZGERALD.

Making the Best of a Bad Packing Job

SOME TIME ago I was called upon to do some repair work on the packing of the piston rod of a large steam pump. The rod was badly worn and scored and the rod holes at the bottom of the packing box and through the packing gland were worn into an oval shape. Because of these defects it was impossible to keep the box steam tight longer than a day or two without tightening up on the gland nuts, even with new packing in the box. The proper remedy would have been to rebore the holes to a true circle and renew the rod, but the owner wanted a less expensive job and I was sent out to the plant to try to improve matters at small cost. A repair man has to satisfy all kinds of demands, some of them quite unreasonable, and he often tries out freak ideas that produce results surprising to himself.

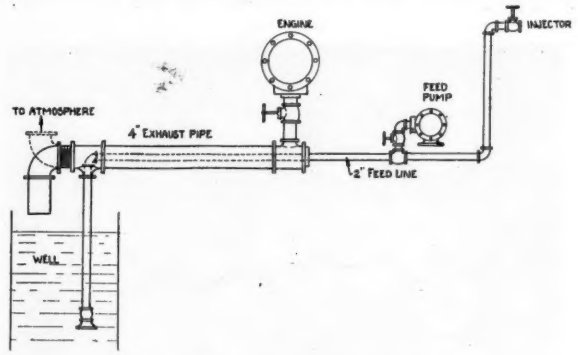
Split brass rings above and below the packing had been tried with small benefit. It so happened that the inside diameter of the box was the same as that of a 1¼-in. globe valve composition disc, I had the round hole in the center of a number of these discs made the same size as the thickest part of the worn rod, then cut the discs into halves, I placed one complete disc in the bottom of the box with a ring of new packing on top of it, then another disc, then packing, and continued this process until the 6-in. deep box was filled, with a disc at the top. The packing nuts were tightened slightly and the pump started. The packing was tight and continued so with a slight taking up on

the gland nuts about once a week. It seems reasonable to expect that a box filled in such manner would give poorer service than one filled with regular packing. Such was not the case, however, in this instance, and to my knowledge the box continued to give good service for two years using the same set of discs, with new packing between them every few months. The combination of defective rod, oval holes, cut discs, and packing made a great improvement over the two cut brass rings and packing but I never could figure out why it did so.

JOHN THORN.

Contriving a Feed Water Heater

IN A steam sawmill in Maine the feed water for the boiler was taken from a well 22 ft. from the engine. No feed-water heater had been provided and the boiler was usually fed by an injector. At times the injector would get out of order and it would then be necessary to feed cold water with the feed pump for a short time, which practice was, of course, bad for the boiler, especially in cold weather.



FEED WATER HEATING ARRANGEMENT

The 3-in. exhaust pipe from the engine discharged to atmosphere. A 4-in. pipe was arranged with the 2-in. feed line running through it, as shown in the accompanying sketch, with a loose elbow on the end, which could be turned down to discharge into the well whenever the water was frozen over. With this arrangement in operation, the suction pipe at the pump was too hot to hold the hand on. Later, to make more effective use of the exhaust, a feed-water heater was installed.

Utica, N. Y. M. M. BROWN.

The High Cost of Scenery

IN THE Dec. 1 issue of Power Plant Engineering is presented an interesting editorial, "The High Cost of Scenery," which recalls to my mind something that was said by the late Dr. Steinmetz on the subject of the utilization of the energy of Niagara Falls.

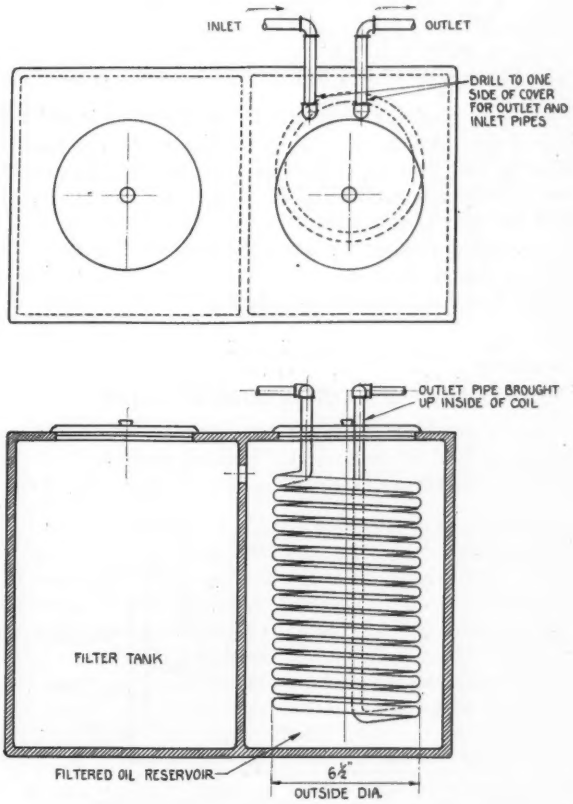
As I remember it, he was in favor of utilizing nearly 100 per cent of the energy obtainable from Niagara Falls. He pointed out that there is no good reason why all of the energy of Niagara should be allowed to go to waste especially during the night when the spectacle is scarcely visible anyway. For the sake of sight-seers, water could be allowed to pass over the falls during certain hours of the day, that is, at off-peak periods. Spectators would then have the advantage of seeing a sight that cannot be seen now, namely, the entire stoppage of all water flowing over the falls and turning it on again. That, in the opinion of the writer, is alone worth the cost and effort of making use of all of Niagara's water.

I do not question but that at some future time, when fuel is scarce, and more expensive, Niagara Falls will be entirely shut off and the water will be allowed to run to waste only on rare occasions. Why wait until we are compelled to do such a thing? Why can we not be sensible now?

Newark, N. J. W. F. SCHAPHORST.

Small Oil Cooling System

NOT LONG ago we found that, for some reason, the lubricating oil on our several uniflow engines was being returned to the reservoirs at a temperature considerably


INLET
OUTLET
DRILL TO ONE SIDE OF COVER FOR OUTLET AND INLET PIPES
OUTLET PIPE BROUGHT UP INSIDE OF COIL
FILTER TANK
FILTERED OIL RESERVOIR
6½" OUTSIDE DIA.

APPARATUS FOR COOLING LUBRICATING OIL

higher than it should have been. To eliminate the necessity thus imposed of feeding hot oil to the engine, we improvised a cooler as illustrated in the accompanying sketch.

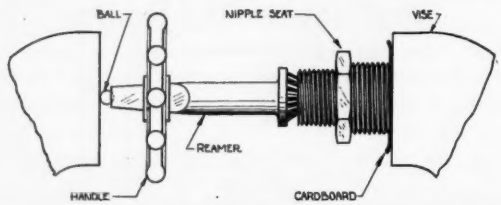
We made a 6½-in. diameter coil of ½-in. copper tubing and inserted it in one of the two compartments of the oil reservoir on the engine. We then connected up the ends of the coil to a cold water supply.

Ordinarily the temperature of the water entering is about 60 deg. F. and it leaves at from 64 to 66 deg., reducing the oil temperature some 10 or 15 deg., depending, of course, on the relative amounts of water and oil circulated and on the length of the coil.

Columbus, O. JOSEPH MCCUE.

Using Small Reamer Without a Bonnet

WE RECENTLY had to face and grind in the seats of some small drain valves to a pump. There was a reamer of the correct taper and size on hand but its shank and the bonnet for it could not be made to suit the purpose. The accompanying sketch shows how the reamer was held to the seat and the reamer turned. A small steel bearing ball was put into the lathe center hole at the handle end of the reamer. The small valve seat nipple was held from



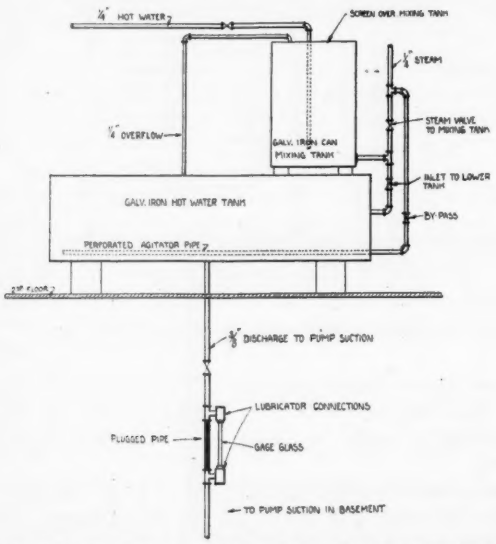
ARRANGEMENT FOR REAMING OUT NIPPLE SEATS

slipping by placing a strip of cardboard between it and the face of the vise jaw. By lightly closing on the vise handle after the ball, reamer, and nipple were lined up, the reamer was turned by means of a globe valve wheel handle slipped over the part of the shank. A little care had to be used, of course, in placing the parts between the vise jaws but the job was as good as if the reamer had been held and forced by a bonnet made particularly for the purpose.

F. W. B.

Boiler Compound Feeder

SOME TIME ago we found it advisable to provide some means of feeding boiler water treating compound to our boiler. The apparatus shown in the accompanying sketch



HOMEMADE DEVICE FOR FEEDING BOILER COMPOUND

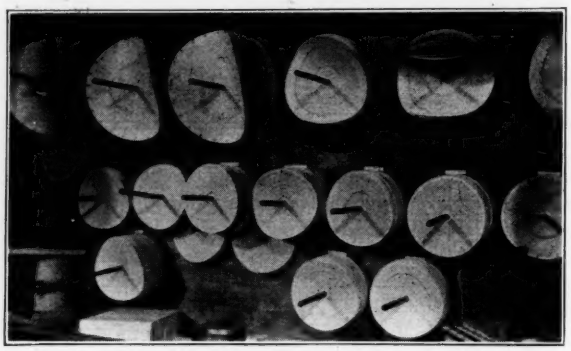
was devised by one of our men and installed. Although the device was made up from scrap material found around the plant, it works admirably.

To operate this feeder, the quantity of compound needed for the day is dissolved in hot water and poured through the screen into the mixing tank, the valve in the inlet to the tank below being closed. The valve in the hot water line to the mixing tank is then opened and the tank is filled two-thirds full. Steam is then turned into the tank until the compound is thoroughly dissolved. After this the valve in the inlet to the lower tank is opened and the solution is passed into it by gravity. Steam is then turned into this tank through a perforated pipe at the bottom in just sufficient quantity to keep the solution agitated. The valve in the discharge line to the boiler feed pump suction is then opened and the solution is gradually fed to the boilers. The gage glass in this line indicates at a glance the rate of feeding.

Davenport, Iowa H. G. HAMMOND.

Convenient Method of Filing Recorder Charts

ORDINARY METHODS of filing recorder charts on fixed pegs are inconvenient when it becomes necessary to turn back through old files. The method shown in the accompanying picture offers the advantage that any set of charts



INDIVIDUAL FILES CAN BE EASILY MOVED FROM THE CABINET FOR INSPECTION

can be removed as a unit from the file cabinet. This is accomplished by driving a peg into a round base board which is hung in the cabinet by means of a hook and eye.

With this arrangement a complete file to can be removed from the cabinet and taken to a table or desk where one or more charts can be conveniently found. This removable file readily lends itself to the study of a chart without removing all the charts ahead of it from the peg. This overcomes in a great measure the inconvenience and trouble resulting from carelessly refiling charts which have been removed from the peg.

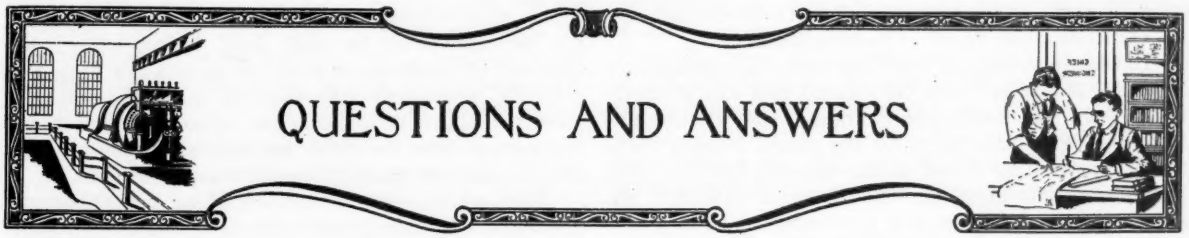
Ludington, Mich. D. LAIDLAW.

Hot Lead as a Heat Reservoir

ON PAGE 154 of the Jan. 15 issue, Mr. Noble takes exception to my letter in the Nov. 15 issue with the statement that he could not understand why I carried a pot of melted lead up several flights of stairs to do a soldering job.

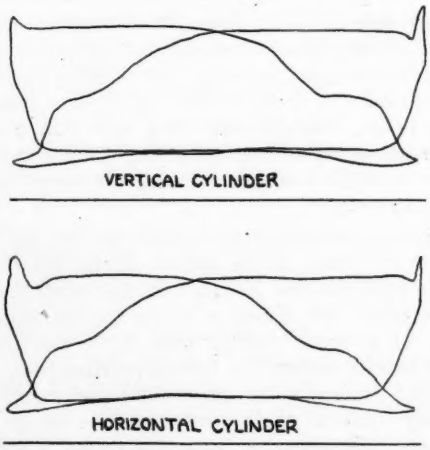
My reason for doing the job in that manner was simply that there was no heat available in any other form at the place that I wanted to work. The hot lead simply served as a heat reservoir at a temperature suitable for heating my soldering iron.

Winnipeg, Man. C. RYE.



What Can Be Done to Better These Diagrams?

I WOULD highly appreciate an opinion from readers of Power Plant Engineering on the accompanying indicator diagrams. They were taken from a simple 12 by 11-in. variable speed angle engine. The upper diagram was taken



INDICATOR DIAGRAMS FROM A SIMPLE ANGLE ENGINE

from the vertical cylinder and the lower, from the horizontal. The engine operates on a boiler pressure of 140 lb. and 1 lb. back pressure, running at 300 r.p.m. By integrating these cards it is found that the total mean effective pressure of the vertical cylinder is 42 lb. and that of the horizontal, 40.5 lb. G. W. C.

Central Station vs. Isolated Plant

REFERRING TO O. P. I.'s question regarding changing to central station power, an offhand opinion would be that with such a large fraction of the exhaust steam useful for heating it would be much more expensive to purchase power unless the present equipment is in such bad shape that much of it must be replaced.

The data given is too incomplete to give an accurate comparison but the general method can be outlined. O. P. I. can get the actual figures from his office books and change it to suit his exact conditions.

Assuming the most unfavorable conditions for the steam plant and most favorable for purchased power, we may consider the coal of poor quality and the engine in such shape that it requires 4 lb. of coal per delivered horsepower or the output will be 111 b.hp. Assuming a transformer and motor efficiency of 82 per cent, this will require $111 \times 0.746 \div 0.82 = 101.2$ kw. or for a 9-hr. day 910 kw.-hr. It is doubtful whether this energy can be obtained at less than 2c per kw.-hr. and under such conditions lighting current would probably have to be paid for at a higher rate, though this will be neglected.

The coal consumption on heating alone works out to about 50 lb. of coal per degree difference between inside and outside temperature, per day and, taking a fair average for the central states of 5 mo. heating season (November to March inclusive) with 20 deg. difference and 25 working days a month, the cost with purchased power, neglecting items not directly affected will be

Electric power—12 mo. of 25 days, 910 kw.-hr. at $0.02	$5,460.00
Coal for heating—5 mo. of 25 days, 1000 × $5 ÷ 2000	312.50
Fireman— 5 mo. of 4⅓ wks. at $25	542.00
	$6,314.50

On coal alone, running the Corliss, it will probably be possible to average 3800 lb. per day considering summer conditions with free atmospheric exhaust so taking

Coal—12 mo. of 25 days, 3800 × $5 ÷ 2000	$2,850.00
Engineer-fireman—12 mo. of 4⅓ wk. at $40	2,080.00
Extra supplies and oil at $25 per mo	300.00
	$5,230.00

It will thus be seen that it can scarcely fail to cost 20 per cent more to operate on purchased power and if it is not possible to obtain the low rate estimated or the present quality of coal and engine efficiency are better than assumed, the difference will be still greater.

The field for central station power in displacing present isolated plants is in small plants having excessive labor cost compared with total number of horsepower hours developed and where little heating or process steam is required. Where the isolated plant must include capital charges, as would be the case if additional machinery had to be purchased or if it were a new plant the situation is different and might favor purchased power where the same factory, having the plant already installed and able to dispose of it at only a small fraction of its cost would not.

In the present instance, unless the transmission is already electric the purchased power proposition will be still more undesirable by the capital charges against the cost of the motors that must be purchased.

New Haven, Conn. H. D. FISHER.

Would the Installation of a Stoker Be Advisable?

ON PAGE 205 of the Feb. 1 issue of Power Plant Engineering, C. W. asks concerning the advisability of installing stokers under his three horizontal return-tubular boilers. He thinks that at present he is using too much coal but he does not give his reasons for his attitude on this point.

If the boilers are working at much less than their rated capacity they may use much more fuel per horsepower produced than if they were worked at or above

capacity. Scale accumulations in the boiler would decrease the evaporation per pound of fuel consumed.

In such small units I would not advise the installation of stokers as long as it is possible to get men with strength to fire them. It would mean the raising and resetting the three boilers to make room for the stokers beneath them and the installation of coal storage bin over head and coal handling equipment which would be quite expensive for such a plant. If, however, a new water-tube boiler, the capacity of which was equal to the three return-tubular boilers were installed, it would be necessary to use a stoker, as a man would not be able to handle a fire properly in such a large firebox, by hand firing.

Then, too, the care and upkeep of the stokers and the expense of repair parts is considerably more in some types of stokers on small size boilers, per horsepower produced, than on larger units. It would be far cheaper to install an oil burning system with storage tank and heating apparatus. The bridge walls of the present setting could be removed and the burner placed in the ash pit doors. This would eliminate all coal and ash handling expense and the plant would be far cleaner and easier to operate than with mechanical stokers.

Cambridge, Mass. R. A. Cultra.

Referring to C. W.'s question regarding the installation of stokers under medium sized return-tubular boilers, I am confident that the spending of only a fraction of the cost of stokers in investigating and remedying the woes and outstanding defects of the present installation will give every economy that could be obtained from stokers of this size.

For small grates which the fireman can see and reach without unreasonable effort and for moderate capacities, good hand-firing with stoking grates has consistently beaten out stokers on comparative tests which I have witnessed and on several occasions has run up to 75 per cent efficiency. Considering that the radiation loss from such a small boiler will run up to 10 or 12 per cent, this compares favorably with the 80 per cent efficiency figures obtained with stokers on large boilers where the radiation loss is only 3 to 5 per cent.

I would therefore suggest to C. W. to check up the condition of his settings, stop up all air leaks in brickwork, rear arch, etc., see that the top of the shell is well insulated, measure the distance from grate bars to bottom of shell and if possible increase this to 36 or 42 in., arrange for periodic tube blowing or permanent soot blowers, watch the ash pile to see that no excessive amount of coke is getting away, get a hand CO_2 machine and follow up combustion conditions so as to give the fireman a chance to show the best he can do and I believe that he will get more in this way than with stokers and at a fraction of the expense. It is also possible that the trouble is not with the boilers but something else around the plant is wrong and causing the excessive coal consumption so that a measured water and coal test might be an excellent thing.

Hand stokers, of which there are several on the market, have not always shown up well on capacity where the draft is limited and require fully as much work as hand firing to obtain the same economy. They do, however, have an advantage in reducing smoke as they compel a coking system of firing. The single retort underfeed stokers are probably the best form for small boiler units either horizontal return-tubular or water tube, but are rather expensive per horsepower in small sizes, do not make a big reduction in labor unless there are quite a few units and complete mechanical coal handling system is installed. Also the apparent efficiency is reduced by the power necessary to drive the stoker mechanism, forced-draft fan, and the plant economy by the added repair expense.

From general observation I would say that unless special conditions such as smoke prevention require it installing stokers on units of less than 300 hp. or in a plant of less than 800 hp. is a doubtful economy as while good hand firemen are undoubtedly scarce they can be trained and it is well worth doing.

New Haven, Conn. H. D. Fisher.

Refrigerating Plant Operation

In the Feb. 1 issue of Power Plant Engineering, page 203, J. B. requests some information on refrigerating plant operation, in charging ammonia into a refrigerating system, such as J. B. is operating. It is not necessary or advisable to open the expansion valve more than the usual amount required for normal operation. This is to prevent any slugs of liquid ammonia reaching the compressor and probably damaging it.

In charging ammonia into a larger system, the expansion valve or valves can be opened several turns, as the expansion piping is long enough to evaporate all the liquid ammonia into a gas before it enters the ammonia compressor. In a system having 1200 ft. or more of 2-in. direct expansion piping in the evaporating side of the system, the probability of any solid liquid reaching the compressor (due to the expansion valves being several turns open) when charging one or two drums of ammonia, is remote.

There are several methods of determining when a refrigerating system needs additional ammonia. Two of the best and surest methods are as follows:

When, operating at normal capacity, if it becomes necessary to open the expansion valves more than one-quarter turn in order to keep up the back pressure, it indicates a lack of ammonia in the system.

If the liquid ammonia receiver is equipped with a gage glass, it becomes quite simple to determine when the system needs additional ammonia. As soon as the liquid level in the receiver becomes low enough so that the outlet pipe going to the expansion valve is exposed or not covered with liquid thereby holding what we call a liquid seal over the end of the outlet pipe, it is necessary to charge in more ammonia to raise this liquid level in the receiver to the proper point.

Operating a plant without a liquid seal is one of the prime causes of a plant losing efficiency or running under capacity. When the charge of ammonia in a system becomes so low that the liquid seal is lost, hot ammonia gas from the condenser is blown through the receiver and out to the expansion valves and into the evaporator.

The best method of pumping out the liquid receiver in a compression plant is to close the liquid valve between the condenser and the liquid receiver, keep the expansion valve open and pump down the system (low pressure side) to a vacuum, then close the expansion valve, after which the receiver can be opened up and the necessary repairs made.

All the ammonia in the system will be stored in the condenser. As a matter of safety, it is well to operate the compressor slowly when pumping out, as outlined above and keep plenty of water running over the condenser.

Chicago, Ill. C. E. ANDERSON.

IF THE charge in the refrigerating system J. B. is operating is too low and 100 lb. of ammonia is enough to bring the charge up to normal the system is so small that the liquid will easily fill the evaporating coils and flood over to the compressor, hence I suggest that in charging the ammonia be allowed to start entering the system with the expansion valve opened to its normal position and then when the back pressure starts going down it is safe to open up wide. When the pressure is down to atmospheric, the drum is empty.

If there is not a liquid sight glass on the receiver, a low ammonia charge will be indicated by the warming up of the liquid ammonia pipe on the high pressure side of the expansion valve and the ammonia will pass through the valve with a rattling sound. The back pressure will also be low and the compressor will heat up.

The receiver can be emptied by passing the ammonia to the evaporating coils and storing it there.

When the machine has just been stopped and the head-pressure is highest, shut off the condenser-water and open the expansion valve. The condenser pressure will blow the liquid and some gas into the low-pressure side; when the pressures on both sides are the same shut the liquid valve at the outlet of the receiver, make sure that the suction and discharge valves at the compressor are closed tight, open the bypasses across these two valves and pump the whole high-pressure side out backwards into the low pressure coils.

When a vacuum is obtained stop the compressor, close the bypass valve and both the receiver and condenser will be empty and in such condition that repairs can be made.

Brooklyn, N. Y. E. MATZAN.

IN REPLY to the inquiries by J. B. in the Feb. 1 issue, let me give a rule that I have followed for years in charging my system with ammonia.

To start this process, it is best to weigh the drum of ammonia before connecting it to the line and after charging you can weigh it again to see that you have emptied it all and that you have the amount of ammonia that you paid for.

First close the valve in the liquid line between the receiver and tank leaving all valves from the ammonia receiver back to the condensers open. Now pump down the suction pressure until it reaches 5 lb. or lower. Connect the drum to the opening provided for this purpose which should be between the valve from the receiver and the expansion valve. Open up valve on the drum slowly to make sure that all your connections are tight. Open the valve on the drum wide open except at the beginning of the operation; do not carry the suction pressure any higher than you would under working condition of your plant.

If you have no gage glass on the receiver, you will know when you have enough in your system by the discharge pressure which will rise to the normal pressure obtaining when your plant is in good working condition. The exact pressure will be determined by the time of year, the temperature of the condensing water and amount of condensing capacity that you have.

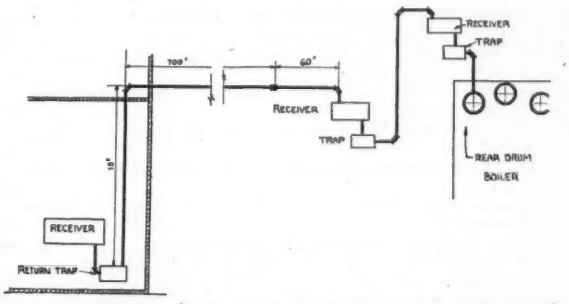
At this time of year when the outside temperature is as low as 50 to 60 deg. F., 150 lb. will be considered good head pressure but in midsummer when the water is not cooled to a lower temperature than say 85 deg. F. your head pressure will run up to 200 and 225 lb. according to the temperature of tank and amount of suction pressure carried.

At no time when charging ammonia into your tank or coil, allow too great a quantity to flow in at a time as this will rush the liquid over into the compressor and possibly cause damage.

Corpus Christi, Texas. R. S. MARTIN.

Are Traps Applicable Here?

REFERRING TO W. J. M.'s question on page 203 of the Feb. 1 issue in which he asks for an opinion as to the use of traps on his return lines, I infer that what he would like to do is to get the condensation from the heating system and from the paper machines back to the boiler without losing more heat than is necessary. At present the returns from the paper mill go to an open heater which allows some waste through the vent and all the condensate from the office heating system goes to the sewer.



SYSTEM OF THREE TRAPS TO RETURN CONDENSATE TO BOILERS

He can put a return trap and receiver on the paper mill side, as the water has to be forced up 10 ft. to the boiler room. Another trap at this point could be used to feed to a point above the boiler from which a third trap could feed direct to the boiler.

To save the condensate from the office building, store house and hospital it will be necessary to use high pressure steam to work the trap. Raising the pressure somewhat on the system should overcome the trouble in this case. If he wants to use two traps, one in the office and another in the mill, he can get results with the present system but I would suggest that he either increase the pressure on the system or run a high pressure line to the trap.

Springfield, Mass. L. N. WEBSTER.

AS THE RESULT of exhaustive research work, the manufacture of 66,000-v. single conductor cable was for the first time placed on a commercial basis in 1923. The cable produced was for the Cleveland Electric Illuminating Co., and can transmit upward of 33,000 kw., at 66,000 v. It is slightly over 3 in. in diameter and requires 125,000 v. to puncture. The previous maximum potential for conductor cable in the United States was 44,000 v.; cable of this rating being utilized for the underground circuits of the New York Edison Co.

POWER PLANT ENGINEERING

Trade Mark, Reg. U. S. Pat. Office

537 South Dearborn Street, Chicago.

Published by the Technical Publishing Co.

Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the act of March 3, 1879. Issued the 1st and 15th of each month. Established over 27 yr.

Subscription price $2.00 a year in the United States and all its possessions. Canada $2.75 a year. All foreign countries $3.50 a year.

Copies of current issue, 15 cents; of back issues, 25 cents.

Copyright, 1924, by Technical Publishing Co.

Member, Associated Business Papers.
Member, Audit Bureau of Circulations.

New York Office, 150 Nassau St.

Circulation of this issue, 21,800.

CONTENTS

Salt Manufacturer Installs 3625 Kw. Illustrated....317
Water Power Economy Overestimated....322
Correct Lubrication for the Steam Turbine. By Claude C. Brown....323
Generation of Power with Factory Refuse. By F. Johnstone-Taylor. Illustrated....326
Burning Oil Under Power Boilers. By R. F. Burke. Illustrated....328
Saving Due to Improved Efficiency. By M. G. Flesher. Illustrated....330
To Regulate Fuel Expense, Control Draft. By James F. Beard. Illustrated....331
Tests of a Powdered Coal Plant. Illustrated....334
Diesel Engine Fuel Valves—I. By H. F. Birnie and R. C. Baumann. Illustrated....336
Quarter Turn Rubber Belt. By N. G. Near. Illustrated....338
What About the C. E.? By James E. Noble....339
Operation of A. C. Generating Apparatus—III. By V. E. Johnson. Illustrated....339
Pulsations Due to Synchronous Motor Drives. By Quentin Graham. Illustrated....342
Research, the Mother of Industry....344
Printed Instructions and Their Preparation....345
Long Range Water Level Indicator. By C. W. Geiger. Illustrated....345
Operating a Small Refrigerating Machine. By H. Noone. Illustrated....346
Intermittent System of Refrigeration. By W. F. Schaphorst. Illustrated....347
Relation Between Heat and Temperature. Illustrated....348
Letters Direct from the Plant: Does the Damper Work Properly? Making the Best of a Bad Packing Job. Contriving a Feed Water Heater. The High Cost of Scenery. Small Oil Cooling System. Using Small Reamer Without a Bonnet. Boiler Compound Feeder. Convenient Method of Filing Recorder Charts. Hot Lead as a Heat Reservoir. Ilustrated....350
Questions and Answers: What Can Be Done to Better These Diagrams? Central Station vs. Isolated Plant. Would the Instalation of a Stoker Be Advisable? Refrigerating Plant Operation. Are Traps Applicable Here? Illustrated....353
Editorial: Build When It Is to Your Advantage. Overall Efficiency....356
Off Duty....357
Automatic Hydro Plant in North Carolina. Illustrated....358
Niagara Power Costs Are Low....358
Ingersoll-Rand Co. Develops New Type Riveting Hammer. Illustrated....359
An Electric Contact Type Temperature Controller. Illustrated....359
Steel Case Turbines Designed for High Pressures....360
Detroit to Build Own Plant....360
Davis Bridge Dam Is Plugged....361
Consumers Power Co.-to Spend $15,000,000 this Year....361
Starter Permits Starting Motor Under Load. Illustrated....362
Tennessee Power Companies Win Merger Case....363
Wolverine Power Co. Building Four New Plants....363
Novel Method of Anchoring Transmission Towers....363
News Notes....363
Books and Catalogs....364

Build When It Is to Your Advantage

Future load requirements should be the basis for all industrial power plant construction. This requires planning in advance of the time when the load demand makes it imperative that construction begin. The building of a power plant, or additions to an existing plant, are not every day occurrences and under the best of conditions it is a difficult matter to keep such work from seriously interfering with the usual process of manufacturing.

Every manufacturer anticipates that his business will grow and accordingly he studies production methods. For some reason or other this study has a tendency to end abruptly on some invisible line between the manufacturing plant and the power plant. A more or less indifferent attitude is taken towards the latter, although productive machinery is continually being replaced with that of a more approved design.

This policy results in increasing the burden already carried by the neglected power plant. It can be continued only by bolstering up the old plant by such wasteful methods as the use of higher priced fuels and the occasional addition of units similar to the old ones which have been operated for years.

There is nothing constructive in this policy; the future is being disregarded and a breakdown must come at a time when the demand for manufactured products is the greatest. A policy of this kind is directly opposite to that of the central station manager who is also a manufacturer and who builds in advance of his estimated load requirements. The central station manager knows that it is his problem to anticipate and meet, without interruption from any cause, the future requirements not only of his present customers but also of new customers. He cannot take the time to build a station when customers are clamoring for service, neither can the manufacturer afford to curtail production during the construction period of a power plant.

Many manufacturers can profit by making a study of the methods by which the central station manager solves the problem of planning and building for the future.

Overall Efficiency

In the operation of power plant equipment, small variations in the efficiency of any particular unit are often unnoticeable and it may not be thought worth the extra effort necessary to maintain a unit at its topmost efficiency. It must be remembered, however, that the overall efficiency of a plant is dependent upon the individual efficiencies of its component units and that a loss of two per cent here and two per cent there may soon total up to a loss of 10 or 15 per cent. It follows, therefore, that if we can effect a saving at any one point and another, at another point, the sum total of these savings, even though they be slight in themselves, will increase the efficiency of our plant say, 15 per cent.

This point is often overlooked by plant owners even though it is realized by the plant operator. The owner assumes that after he has installed equipment that is reasonably modern and if it operates at somewhere near its rated efficiency, he is getting the most for his money. His engineer in an endeavor to secure instruments which would make possible a slight increase in the efficiency of a particular piece of equipment, often fails to convince him, that his suggestion has any economic value.

In considering efficiency, we must consider the plant as a whole. It matters little whether our boiler efficiency is

65 or 70 per cent, if we waste twenty per cent of the available energy in the steam in inefficient steam using apparatus. If, on the other hand, our engines, pumps, turbines, etc., are all operating at their maximum efficiency and making the best use of the available steam, it will be well worth while to pay attention to the boiler efficiency.

Power plant losses are generally hidden away in small parcels and for this reason it is easy to overlook them. Every one will agree that no engineer or plant owner would not tolerate a piece of equipment in the plant the efficiency of which ran 15 or 25 per cent below the possible efficiency. Such apparent losses, if they did exist, could not continue very long without having somebody notice them. So in most plants, the efficiency of any particular piece of equipment is pretty certain to be somewhere near its possible efficiency.

Now while these trifling losses may not amount to much where the individual piece of equipment is concerned, all these trifling losses added together serve to decrease the overall efficiency to a considerable extent. It is imperative, therefore, that these small unnecessary losses be eliminated.

In presenting arguments to the plant owner for improved equipment or instruments, which in themselves may not make a spectacular showing, the engineer will do well to keep this point of overall economy in mind. It may serve to clinch his argument.

Off Duty

We are not personally acquainted with the honorable gentleman in Congress who recently introduced a bill to decimalize the weights and measures of the United States but he reminds us of another gentleman who at one time introduced a bill somewhere in which he proposed to fix by law the relation between the circumference and the diameter of a circle at exactly three; no more, no less.

Both of these gentlemen undoubtedly introduced their respective bills in good faith and with perfectly good intentions. The latter gentleman especially must have been actuated by highly altruistic motives for, when you stop to think about it, the adoption of his bill would have simplified our calculations to a considerable extent. Think what the absence of that mysterious number 3.1416 would mean to humanity. What, indeed, could be sweeter than a nice round circle whose circumference was exactly three times its diameter? Of course it is true, that with such an arrangement our circles would be smaller and there would not be as much silver in our dollar but this drawback would be more than compensated for by not having to put up with 3.1416 that mysterious, Pi. In fact we haven't the slightest bit of doubt but that the honorable gentleman thought that the only Pi that had any business having relations with a circle at all was the kind served as dessert.

Suppose for instance that this gentleman had been a contemporary of Euclid and that by pulling the right strings he had been successful in having his bill made a law, think what endless mental effort he would have saved posterity! Think of the long line of quadrature experts and circle squarers that would have been able to direct their effort towards more fruitful although perhaps less fascinating sources! Don't tell us the gentleman was not a friend of humanity.

The world, however, is heartless and turned the gentleman's proposition down with a coldness that makes us shiver. Why? Simply because some fool mathematicians (so the gentleman called them) said it couldn't be done. The mathematicians are always taking the joy out of life. Perhaps some day some good soul will succeed in passing a law which will provide for the complete extermination of all mathematicians together with all their complicated theories about Pi and diagonals and trisections, etc. Then, by gosh, we'll make some circles that *are* circles—circles that will not be encumbered by a lot of indeterminate ratios. Members of congress, you know, have a certain aptitude for such problems and they would, no doubt, evolve some interesting geometrical conceptions. Their ability along this line is well exemplified by their intense interest in studying the curvature of the Teapot Dome oil leases. This particular curvature appears to be far greater than any mere mathematician might have supposed, but Congress saw through it and was not long in making it known.

But we have digressed. We started to talk about the honorable gentleman who wants to decimalize our weights and measures. His plan, briefly, is as follows:

"The linear base for the weights and measures of the United States shall be the foot. The foot shall be divided decimally into 10 digits, 100 lines and 1000 points. Ten feet shall constitute a Pole.

"The ounce shall be the weight of a cube of the tenth of the foot of water at maximum density. The ounce shall be divided decimally into 10 dimes, 100 carats and 1000 mils, etc., etc."

In other words, he proposes what is virtually the same as the metric system now used in Europe but with the foot as the standard instead of the meter.

This, however, is not all. Indeed, no, the gentleman is extremely thorough and has provided conversion factors to change over to the metric system. In addition to the above units he retains our present inch and fixes the ratio between inches and millimeters at 10 to 254! Simple as Pi. Try it yourself and see how easy it is. The gentleman's ambition commands our admiration. He wants to change the length of the meter!

If we adopted his system we should have all the confusion and complication of changing our weights and measures that would result from our adopting the European metric system but should gain absolutely nothing so far as standardization is concerned. The only logical argument for the adoption of the metric system in this country is that it would result in a standard system of weights and measures throughout America and Continental Europe. This, no doubt, would be an advantage but the expense and the confusion which would result from the change does not warrant it. And now, the gentleman referred to wants to create the same amount of confusion and expense but with the difference that after we get all through we shall be no better off than before we started!

A brilliant plan, to be sure! Ever since it was first disclosed we have marveled at the vast amount of intellectual effort that must have been expended in creating it. Of course, while the confusion resulting from its adoption would be enormous, just think of what it would mean to the ruler manufacturers. Think of the vast amount of business it would create for the tape measure makers!

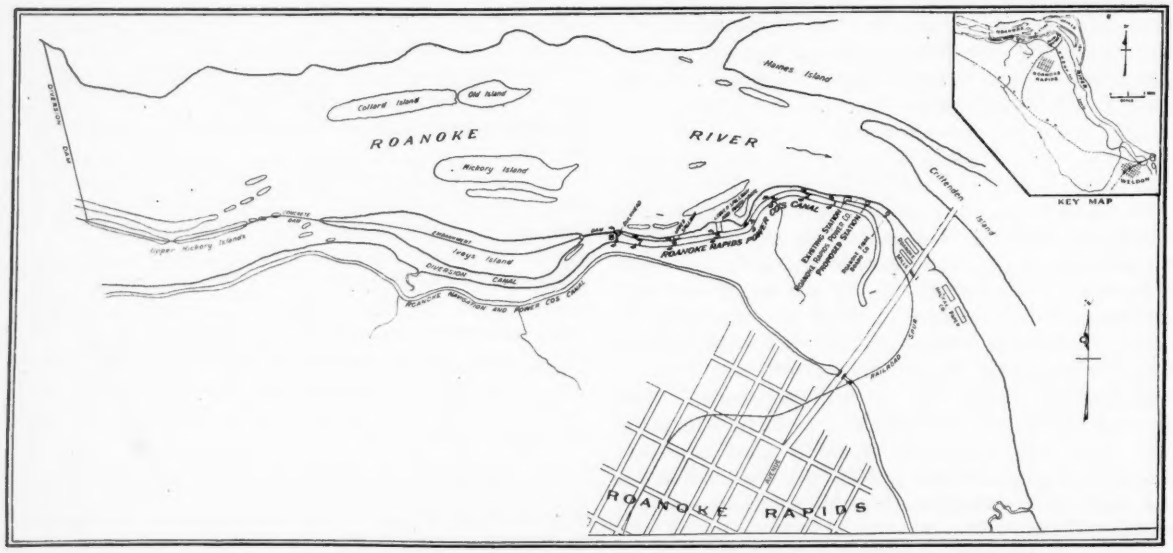
The honorable gentleman has our sympathy, however, for we realize the outcome of his proposal. The world is still as heartless as ever and it will discard his plan just as it did that of the gentleman of the circle. It's a cruel world.

Automatic Hydro Plant in North Carolina

AN INTERESTING hydroelectric project is being developed in North Carolina, where the Roanoke Rapids Power Co., of Roanoke Rapids, North Carolina, is building a 3000-kv.a. automatic hydroelectric station to supplement its present power station at Roanoke Rapids, about 100 mi. from the mouth of the Roanoke River.

It is planned to connect the new automatic station to the existing station by a cable tie line. Its operation will be controlled from the present station by means of two switches, one, actuating an oil circuit breaker in the existing station will cause the automatic station to start up and tie in with the 6600 v. bus in the existing station, and the other switch to regulate the load to be carried.

The hydroelectric unit being installed in the new power station consists of a 3200-hp. vertical shaft, propeller type water wheel, furnished by the I. P. Morris



LOCATION MAP OF ROANOKE HYDROELECTRIC DEVELOPMENT

Water for the new development and present station is supplied from a drainage area of about 8000 sq. mi., and adequate water will be available for operating the automatic station at maximum capacity for a period of about 9 mo. in an average year.

The company's present station contains two 750-kv.a. and one 1500-kv.a. horizontal hydroelectric units operating under an average net head of 30 ft. The water wheels were furnished by S. Morgan Smith Co. and are direct connected to General Electric Co. generators. The station also includes two General Electric steam turbines, the capacities being 625 kv.a. and 1875 kv.a. The present head works at the head of the power canal is equipped with 13 timber sliding gates, 12 being 6 ft. by 12 ft. and one 8 ft. by 8 ft. This entire structure will be altered, and the present old timber gates replaced by four 14 by 21-ft. structural steel tainter gates, which will be operated by a motor driven hoist controlled from the present power station about three-quarters of a mile down stream.

Department of The Wm. Cramp & Sons Ship and Engine Bldg. Co., to operate at 164 r.p.m. under an available net head of about 30 ft. The wheel will be furnished with a Woodward motor driven flyball governor. The generator, furnished by the Allis-Chalmers Manufacturing Co., is of 3000 kv.a. capacity, 6600-v., 3-phase, 60-cycle. The automatic equipment and switchboard for the new station will be furnished by the General Electric Co.

Stone & Webster, Inc., of Boston, Mass., has been retained to design and construct the new power station, and make the necessary alterations in the canal head works.

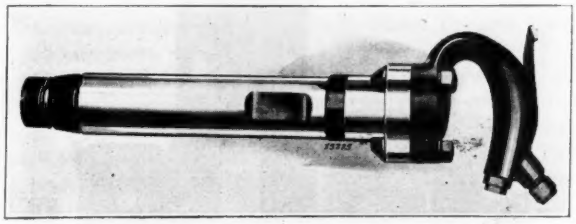
Niagara Power Costs Are Low

NIAGARA FALLS POWER CO. has reported net earnings for 1923, after depreciation of $2,562,000 equivalent after preferred dividends to $8.39 a share on the 173,244 shares of $100 par common outstanding. This compares with a net of $2,394,000 or $9.21 a share on 145,219 shares in 1922.

This company leads the power industry in electrical output, having produced 2,595,847,000 kw.-hr. of hydro-electric energy in 1922. If this output had been produced by steam, it would have required the burning of some 3,000,000 T. of coal. The operating expenses during 1923 amounted to $1,199,991. When the 210,000 hp. additional capacity which the company is now adding have been installed, they will have a total rated capacity of around 610,000 hp.

Ingersoll-Rand Co. Develops New Type Riveting Hammer

IN THE ACCOMPANYING illustration is shown a new type of pneumatic riveting hammer recently placed on the market by the Ingersoll-Rand Co., of New York. The outstanding features of this riveter include



NEW INGERSOLL-RAND RIVETING HAMMER

bolted construction for holding the handle to the barrel, heavy suction valve with liberal bearing surfaces; combination poppet and piston type throttle valve; power in excess of all ordinary requirements; low air consumption and exceptionally easy operation. The new style hammers are manufactured in three styles and are available in a complete range of sizes from a 5-in. to a 9-in. stroke. Each size of this riveter can be secured with any one of three types of barrels and with either outside or inside trigger handles. Control is sensitive, ranging from a light tap to a heavy blow, entirely at the will of the operator. The valve is a sturdy sleeve made from special alloy steel. It has liberal bearing surfaces and its walls are free from holes or ports which so often are the starting points for checks or cracks. It operates in a valve box of strong construction, located in the head of the barrel. The valve box is constructed with a solid end which enables it to be easily taken apart by the use of a piston for the removal of the valve, without recourse to the use of a screwdriver or similar instrument with subsequent danger of injury. This construction also insures a compression chamber in the valve box which cushions the piston on the return stroke and prevents the piston from striking the handle.

Exhaust is through the side of the barrel near the handle and can be deflected in any direction desired by the operator, by merely turning the deflector.

An Electric Contact Type Temperature Controller

THIS ELECTRIC CONTACT Controller, which has been developed by the C. J. Tagliabue Mfg. Co. of Brooklyn, N. Y., consists essentially of a dial indicating thermometer, the pointer of which is actuated by the usual mercury, vapor-tension, or gas-filled thermostatic system, depending on the desired range and other specifications. The bulb stem is inserted in the oven, furnace, tank or other apparatus where the temperature is to be controlled and is connected by a capillary tube to the case which can be mounted at any convenient location. As the temperature at the bulb increases or decreases, the thermostatic spring uncoils or recoils, thus moving pointer across the scale. The exact temperature existing at the bulb is thus indicated at the case and the responsiveness and closeness of the control may be determined.

Temperature is controlled by the following arrangement. On each side of the indicating pointer is located an arm. These arms are mounted on the axis of the pointer and have mounted on them auxiliary contactor arms. By adjusting the left-hand arm to point to the minimum tem-

TAG ELECTRIC CONTACT TEMPERATURE CONTROLLER

perature, and the right-hand arm to point to the maximum temperature, control is established between these two points in the following manner. When the indicating pointer reaches the minimum temperature, its contact block makes an electric contact with the left-hand arm closing a circuit through binding posts L and C which operate through a relay to close the circuit of an electric heating coil. The current continues to pass through this heating coil until the indicating pointer reaches the maximum temperature and makes an electric contact, with the right-hand arm closing a circuit through binding posts C and H.

This controller may also be used for starting and stopping a motor by means of a motor-starter as in the case of an automatic refrigerating unit. The least difference between minimum and maximum control temperatures is approximately $\frac{1}{32}$ in. It cannot be expressed in degrees of temperature unless the range of the scale is known.

An adjusting screw is provided for simultaneously lowering or raising the minimum and maximum temperatures at which the indicating pointer closes the circuit. This is accomplished by moving the arms together as a unit to the right or left.

By turning the adjustment screw provided within the case, the difference between the minimum and maximum temperatures may be changed. This is accomplished by having the left contact arm move toward or away from the right contact arm. The greatest difference between minimum and maximum control temperatures is approximately $\frac{1}{2}$ of the total range.

Head temperature correction is provided. By means of a bi-metallic strip interposed as a link between the

spiral spring and the spindle of the indicating pointer, fluctuations in temperature at the case of the instrument are corrected automatically. This compensating device is identical with that used in Tag Recording thermometers. The case is japanned-iron with a nickeled-brass door, 8 in. in diameter.

Steel Case Turbines Designed for High Pressures

AN INTERESTING development in the design of small turbines is seen in the new types "GS" and "CS" steel case turbines recently placed on the market by the Terry Steam Turbine Co., of Hartford, Conn. These machines are designed especially for use with extremely high pressures and superheats, and are so constructed as to operate under these conditions without misalinement troubles, casting growth, or undue strain in any part. All the material entering into their construction is of special quality and is inspected with unusual care, the steam passages being hydraulically tested to 1000 lb. pressure. The general construction is of such a nature that shaft alinement is maintained under all conditions. The shaft is carried in two heavy pedestal bearings resting directly on the baseplate. The case is supported close to the center line from semi-circular lugs on these pedestals. The pedestals are short, stocky and of ample lateral spread. They are supplied with liberal oil reservoirs and water cooling coils. This method of construction insures perfect alinement regardless of casing distortion since there is no hot metal between the bearings and the base-plate.

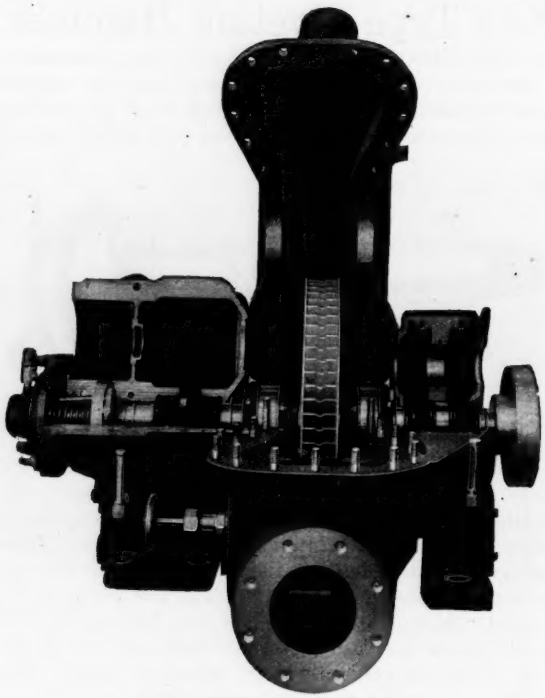
Casing proper and the governor valve body are of electric furnace steel, while the governor valve, stem and seats, hand valves and nozzles are of monel metal. The turbine rotor is of steel and is made from a solid forging. This rotor it is claimed will stand an unusual degree of superheat, both because it runs in steam at exhaust temperature only and because it is a homogeneous one-piece rotor.

These machines are split horizontally throughout, including the bearing caps and governor housing a type of construction which permits easy access to the interior for inspection or repairs. All steam and exhaust connections are on the lower half of the case which permits complete dismantling of the turbine without disturbing either piping alinement.

Glands are of the carbon ring type, composed of three carbon rings which are enclosed in a separate casing and are permitted to float with the shaft but not turn. Each ring is composed of three segments held together by a garter spring made of monel metal to resist the corrosive action of the steam. The gland casing is fitted with a leak-off space which is located between the two outside rings and is provided with a drain connection.

A centrifugal type of governor is provided. This is mounted directly on the turbine shaft, and is directly connected to the governor valve by simple levers. For handling large valves or where especially fine regulation is required, an oil relay governor is used. Oil supplied under pressure from a pump acts on a piston and positively moves the governor valve. The main governor has only to move a pilot valve controlling the oil pressure on the piston. The governor valve is of the double seated balanced type designed to give the least possible pressure drop. The valve and seats are of monel metal and may be removed without breaking the steam pipe connections. Surrounding the valve proper is a large annular space containing a cylindrical monel metal strainer. This produces perfect steam distribution and protects the valve against an unbalanced steam blast. The strainer also serves to protect the nozzles and wheel from damage by large foreign matter carried over in the steam.

Bearings are liberal in design and are lined with the highest grade of genuine babbit. They are horizontally split so that they may be rocked out of position and



TERRY STEEL CASE TURBINE

replaced without disturbing the casing or rotor. They are flooded with oil by two solid machined brass oil rings which cannot stick.

To reduce radiation, the casing is clothed in a thick layer of magnesia and then covered with carefully fitted sheet iron. The sheet iron is supported by cast iron end rings and bound with polished steel bands.

An interesting type of construction characterizes the wheel. This is made from a single forging of composition steel and the semi-circular buckets or pockets are milled from the solid metal. The blades have large clearance and are further protected by the projecting rims at the sides of the wheel, which would take without damage any rubbing that might occur if the clearance became reduced.

In this type of wheel the jet of steam issuing from the nozzle gives up part of its velocity in its first reversal in the wheel buckets, but still retains a considerable portion of its energy. It then passes a reversing chamber which returns it to the wheel buckets again. This is repeated several times until all of its energy has been given up to the wheel. The power producing action of the steam in the wheel buckets takes place entirely on the curved surfaces at the back of the bucket. As the only function of the blades is to split the steam jet, close blade clearance

is not necessary, and wear of blades is of little consequence. The turbine is of the radial flow type so there is no end thrust.

Detroit to Build Own Plant

DEFINITE DECISION was reached in the City of Detroit Power situation when acting mayor Joseph A. Martin announced the immediate construction of a 60,000 kw. public power plant which will cost $11,600,000. He abandoned the plan of the lighting commissions engineers for an 80,000-kw. plant at a cost of $14,611,000.

Martin at the same time approved a contract with the Detroit Edison Co. which it is expected will save the city $1,250,000 on street railway power costs between now and October, 1926.

This decision was reached by Martin after a month of careful study during which time he had at his services William B. Mayo, chief engineer for the Ford Motor Co.; Alex Dow, president of the Detroit Edison Co. and other noted engineers.

The Detroit Edison Co., through its vice-president, A. C. Marshall, agreed to the cancellation of the present interim contract between his firm and the city. He agreed to a lower rate which means the saving of $1,250,000. The contract would expire October 1, 1926, and by that time Martin expects the new power plant will be completed and will provide the D. S. R. with power.

It is estimated that the new plant will have a capacity of 300,000,000 kw. annually, whereas the city's present demands for power aggregate 242,000,000 annually. The latter figure will probably be increased to 265,000,000 by the time the new plant is completed, according to the figures of H. M. Gould, electrical engineer for the D. S. R.

Martin has evolved a plan for financing the new plant which will be in strict accordance with the laws governing the city's bonding limit. During the first year only $1,000,000 will be spent in the construction work; $4,000,000 will be spent during the second year, and the balance, $6,611,000, raised during the seven months of the third year. The constant increasing of the city's assessed valuation automatically increases the city's bonding limit each year.

Martin has approved of the sale of the Riopelle Street plant of the D. S. R., which, it is estimated, will bring revenue amounting to $1,560,000; which sum will be applied on the cost of the new building.

Davis Bridge Dam Is Plugged

INTEREST IN the Davis Bridge hydroelectric development was revived recently when the large earth dam across the valley was finally completed and plugged. This dam is the highest earth dam in the world, being 200 ft. high, 1200 ft. wide at the base and extends some 1200 ft. across the valley. A description of this project appeared on page 592 of the June 1, 1923, issue of Power Plant Engineering.

From now on, the dam can hold back the floods of the upper Deerfield River in Southern Vermont, and when in a few weeks the spring rains come and the snows melt over the 200 sq. mi. of territory which this section of the river drains, the reservoir will become a lake extending 10 mi. up the valley.

What used to be 800 acres of woodland and 1400 acres of pasture and meadow will be covered by 38 billion gallons of water, conserved to supply, especially in time of summer drought, hydroelectric power to drive the industries of New England.

The final step in the completion of the 200 foot high dam, was to plug the diversion tunnel which has taken care of the river flow in times of flood as well as under normal conditions, while construction was going on from June 1, 1922, to the present time.

This tunnel, 22 ft. in diameter, was drilled through the solid rock of the hillside, to form a giant bypass, 1500 ft. long. That section between the downstream outlet below the dam and the spillway, located within the reservoir 300 ft. upstream from the center line of the dam, was designed to be the permanent spillway tunnel which will take care of the discharge of surplus water when the reservoir is full and running over. The last job was the plugging. The upstream end was cut off by a titanic plug of concrete, located upstream from the bottom of the "gloryhole," the name given by the men to the spillway shaft which rises from the tunnel 185 ft. and convolutes to a diameter of 160 ft. at the top. The method of plugging was interesting. Water was flowing through the tunnel and had to be taken care of while the plug was being put in. A pipe 4 ft. in diameter was laid along the bottom, and a bulkhead was built at the upstream end to divert all the flow into it. The pipe is a permanent fixture, to be used to permit the flow of water when required, and controlled by a valve operated from the ground level 100 ft. above, pistons causing it to open or close.

Midway of the pipe two plank bulkheads were built, each completely filling the tunnel, 9 ft. apart. From the chamber formed between them a hole extended straight up to the ground level. Down the hole the concrete was poured until the chamber was filled solid. The tunnel was plugged tight, all but the pipe which remained imprisoned in the hardening stone. The water will continue to flow through it until the concrete has completely solidified. Then the valve will be closed and the filling of one of the largest reservoirs in the Eastern United States will begin.

Consumers Power Co. to Spend $15,000,000 this Year

ACCORDING TO a recent announcement, the Consumers Power Co., Jackson, Michigan, will spend between $15,000,000 and $16,000,000 this year for improvements and additions to plants and transmission lines. Approximately $13,000,000 will go for electrical construction and equipment. It includes new transformers, voltage regulators, substations, safety appliances and modern switching apparatus.

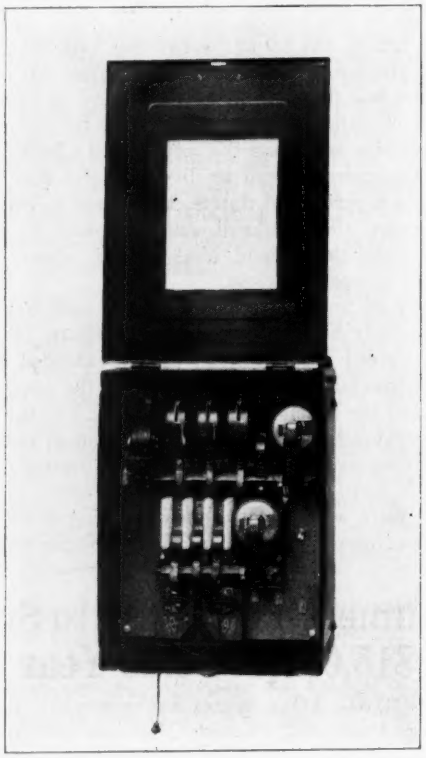
Included in this big appropriation is the cost of finishing the 8000 kw. hydroelectric plant at Alcona on the AuSable River; the 40,000 kw. steam plant on the Saginaw River near Bay City and Saginaw; 20,000 kw. steam turbo generator at the Battle Creek steam plant; 4000 kw. turbine and generator at the new Fulton St. steam heating plant in Grand Rapids with two new boilers. One item of $750,000 is to be devoted to connecting up the new dams of the Wolverine Power Co. on the Tittabawassee River with the Consumers Power Co. system. Provision also is made for preliminary work on the county line water plant near Cadillac. In all 150 mi. of transmission lines will be built this year.

During 1923 the company repeatedly exceeded all past records for peak load on its system. The highest was about 140,000 kw. or upward of 185,000 hp. In 1923 the company generated and distributed a total of 574,031,472 kw.-hr. of electrical energy. Of this 290,484,279 kw.-hr. was water power generation, which represented a saving of more than 10,000 carloads of coal.

Some $2,500,000 is to be spent this year on betterments and extension of the distribution system.

Starter Permits Starting Motor Under Load

IT IS frequently desirable or necessary to start polyphase squirrel cage motors under light load. To enable this to be done without endangering the motor the General Electric Co. has placed on the market a new starter known



AUTOMATIC STARTER FOR SQUIRREL CAGE MOTORS

as the CR-7056-DI. This device is of the primary resistance type and is proportioned so as to give an inrush current of 3½ times the normal full load motor current, thus permitting the motors to develop at least 50 per cent full load torque in starting.

These starters are equipped with a single-step resistor, equal parts of which are connected in each phase. The switching elements consist of a starting contactor, a running contactor and a time-limit accelerating relay whose action is retarded by an alternating current magnetic drag. Overload protection is provided by a thermal overload relay. The starter is of the safety type completely enclosed with a ventilated case. The time interval of the closing of the accelerating relay can be changed from approximately 3 to 8 sec. To shorten or increase the time interval requires but the turning of an adjusting nut.

Tennessee Power Companies Win Merger Case

HOLDING THAT ELECTRICITY in the form distributed commercially for heat, light and power is not a manufactured "article of domestic growth or of domestic raw material," Chancellor James B. Newman, of the chancery court, has decided in favor of the defendant in the anti-trust suit brought by the state against the Tennessee Electric Power Co. and several affiliated companies for which it was formed.

This decision was made in the case of the State of Tennessee upon relation of Frank M. Thompson, attorney general, against the Nashville Railway & Light Co., Chattanooga Railway & Light Co., Chattanooga & Tennessee River Power Co., Tennessee Power Co., Tennessee Railway & Light Co., the Tennessee Electric Power Co. and the Nashville Trust Co. The bills attacked the contracts and agreements entered into by the defendant companies for the purchase by the Tennessee Electric Power Co. of the other power companies as being in violation of the anti-trust laws and common law of the state, and sought to have the contracts declared void and the charters of all the corporations declared forfeited except that of the Nashville Trust Co., which was named as a defendant on account of it having been named as the depository for certain stocks involved in the sale and purchase of the companies.

"Electricity as an energy or force in nature is not susceptible of ownership, and therefore not domestic raw material," the chancellor stated. "There can be no agreement or combination made to lessen, or which would tend to lessen competition in the sale of electricity as an energy or force in nature; until it is generated or manufactured, it is not a subject of property rights, and since it is not manufactured from 'domestic raw materials,' it is not within the statute invoked."

Chancellor Newman held that the agreements entered into between the defendants are not against the public policy of the state, nor interdicted by any principle of common law in force in this state.

He held that the anti-trust law does not apply to public utilties engaged in the manufacture and sale of electricity, and that the view is confirmed by legislation passed in Tennessee since the enactment of the anti-trust law. Chapter 198 of the Acts of 1887 permits corporations, except competing lines of railroad, to lease and dispose of their property and franchises to other corporations engaged in the same business. Chapter 437 of the Act of 1907 empowers corporations to sell, transfer and convey their property and franchises to other corporations, and Chapter 49 of the Acts of 1919 gives the Public Utilities Commission of the State of Tennessee to supervise, regulate and control public utilities, their property, facilities and franchises, and by its provisions no public utility may lease its property, rights and franchises, or merge or consolidate with any other public utility without approval of the commission. Chapter 87 of the Acts of 1923 prohibits any public utility constructing or operating any line in any territory receiving like service from another public utility without first obtaining a certificate from the Public Utilities Commission that the present or future public convenience and necessity requires such construction or operation. It appeared, the chancellor stated, that all agreements and

contracts of the defendants had been ratified and approved by the Public Utilities Commission.

"It is difficult to reconcile with reason or simple justice that the state would authorize a corporation to do certain acts, provide a commission or tribunal to pass upon and approve these acts, and then punish the corporation, by forfeiture of its charter and banishment from the state, for what it had sanctioned and approved," the chancellor said.

Wolverine Power Co. Building Four New Plants

FOUR NEW hydroelectric power plants are being constructed along the Tittabawassee and Tobacco Rivers in Midland and Gladwin Counties, Michigan for the Wolverine Power Co. The machinery for the No. 1 Plant consists of three 1500-kv.a. vertical shaft direct connected hydraulic turbine and generator units with direct connected exciters. The average head on this plant is 26 ft.

Plant No. 2 will have installed two 3300-kv.a. units similar to those installed in plant No. 1, excepting that at this plant the turbines have outside gate mechanisms and have concrete draft tubes. The No. 1 plant has the open flume type turbines and uses steel plate hydraucone draft tubes built by the Allis-Chalmers Mfg. Co. The head at this plant is 46 ft. The hydraulic machinery including the governors is furnished by the Allis-Chalmers Co. while the generators are furnished by the General Electric Co.

Unit No. 3 has installed one generator similar in every respect to those of Plant No. 1, while No. 4 will have one 1500-kv.a. machine similar to that in Plant No. 2.

All plants will generate at 2300 v. 3 phase, 60 cycles and the voltage will be stepped up by three single phase water cooled transformers at the No. 1 and 2 plants while at No. 3 and 4, air cooled transformers will be used. The normal interplant line voltage is to be 35,000. Machinery is scheduled for delivery in May and it is expected to have the plants in operation by August of this year.

Novel Method of Anchoring Transmission Towers

AN INTERESTING method of anchoring transmission towers will be used in the construction of the new transmission line to be built by the Illinois Power and Light Corporation from the power dam at Keokuk, Ia., to Galesburg, Ill. A hole 8 ft. deep and 5½ in. in diameter will be drilled where each leg of a tower is to stand. Dynamite will then be lowered into the hole and touched off, blowing a cavity at the bottom 2 ft. in diameter. Concrete will be poured into the cavity and the legs of the tower set into it. After the concrete hardens, the tower legs will be anchored in solid balls of stone imbedded in walls of earth compressed by the exploded dynamite.

Material for the new line has been contracted for by the Illinois Power and Light Corporation. The Blaw-Knox Co., Pittsburg, will furnish the steel towers; the Aluminum Co. of America, Messina, N. Y., the wire; and the Westinghouse Electric & Manufacturing Co., East Pittsburgh, the insulators.

Construction will commence as soon as the ground is soft enough to work. Engineers expect to have the line finished by fall.

News Notes

PRESIDENT George E. Learnard of the International Combustion Engineering Corporation of New York City, is one of the directors of a new subsidiary corporation which has been formed in Holland to operate in that country and central Europe, including Germany. The new organization will be known as the Carbo Union Co. and will engage in the manufacture and sale of all the equipment which is now controlled by the International Combustion Engineering Corp., such as stokers, pulverized fuel equipment and other combustion apparatus. Besides Mr. Learnard, the directors are Hugo Stinnes, Sr., Hugo Stinnes, Jr. and Alfred Pott, all of Germany and Carl Schwartz, director of foreign development of the International Combustion Engineering Corp.

JOHN W. LANE, former editor of the "National Engineer," died on February 25, at Lowell, Mass. Mr. Lane was born in Portland, Maine, Feb. 19, 1868, and when he was 16 yr. old moved to Providence, where he entered upon his long engineering career. After 15 yrs. of varied experience as engineer he accepted a position as editor of the "Engineers List," a small publication circulated among engineers in the vicinity of New York. In 1901 he became editor of the "National Engineer," which position he occupied for 21 years.

Mr. Lane became a member of the N. A. S. E. in 1889, was elected national vice president in 1893 and president in 1894. His efforts contributed greatly to the success of the "National Engineer" and the organization as a whole.

KENT ENGINEERING CO., district representative of the Conveyors Corporation of America, 326 W. Madison St., Chicago, has changed its address from 504 First National Bank Bldg., to 1110 Farnam St., Omaha, Nebr.

COPPUS ENGINEERING CORPORATION of Worcester, Mass., announces the fact that, Himelblau, Agazim & Co., 30 N. Dearborn St., Chicago, Ill., will act as its Chicago District Representatives and handle the company's entire line of equipment.

C. PHILLIPS KERR, formerly Manager of the 1-ton pilot plant at Milford, Conn., where the Milford Electrolytic Iron Co. was developing a process for making electrolytic iron from sulphide ores, is now engineer in the Mechanical Division of Stone & Webster, Inc., of Boston, Mass.

B. L. KNOWLES, MANAGER of the Publicity Department of the Worthington Pump and Machinery Corporation, died Thursday afternoon, Feb. 14, as a result of a cerebral hemorrhage. Mr. Knowles was 45 yr. old at the time of his death and had spent 28 yr. with the Worthington Corporation. He is survived by his widow and two sisters.

CLEVELAND ELECTRIC ILLUMINATING CO. has ordered complete motor equipment for firing and induced draft purposes in connection with four 3057-hp. boilers now being installed in its 70th St. Power House. The boilers are to be fired with pulverized coal. Sixteen 1½-hp., 230-v., G. E. shunt wound motors will drive the screw conveyors for the pulverized coal. Twelve 100-hp. 450-r.p.m., 2200-v., three-phase, 60-cycle motors will operate the coal crushers. Other equipment will include four 100-hp., 1200-r.p.m., 2200-v. motors, twelve 50-hp., 1200-r.p.m., 2200-v. motors and six 15-hp., 900-r.p.m., 440-v.

motors, all three-phase, 60-cycle, continuous rated, constant speed machines equipped with starting compensators.

In addition to this equipment, there will be eight, 150-hp., 360-r.p.m., three-phase, 60-cycle brush-shifting motors with automatic speed control from full speed to 35 per cent, of full speed. These will drive induced draft fans, two to each boiler.

An effective service chart known as Form N. Y. 298, covering methods of belt joining has recently been issued by the Crescent Belt Fastener Co., of New York, N. Y. This chart, which is in card form, size 3½ by 9 in., covers completely and specifically the means and methods to insure best results under all conditions of work. The indexing is by columns and covers all dimensions of belting from ¾ to 18 in. and larger in width. Specifications given cover leather belting in light, medium and regular; single, double and triple weights; and all kinds of fabric belting, rubber, canvas, balata, hair, etc., by plies. On the back of the card, prices are given. This card is punched so it can be hung where convenient for reference and in many of the larger companies these cards are placed at different points about the plants for ready reference by the men.

Columbus Railway Power & Light Co. is planning the erection of a new 150,000-kw. station to be installed about 10 mi. from Columbus, Ohio. This station will supply power for railway, lighting and industrial purposes to the immediate district, and is laid out for five 30,000-kw. turbine generator sets.

Books and Catalogs

Elementary Hydraulics, by F. W. Medaugh; 5 by 8 in., 144 pages, 71 illustrations; cloth, $2.00; New York, 1924.

To use this book, a knowledge of physics and of mathematics up to algebraic equations is needed. It is an introduction to the further study of hydrodynamic and hydraulic phenomena and is carefully prepared to lead the student from elementary conceptions to the basis for more extended work. Starting with pressures in cylinders, on dams and in pipes and tanks, it goes on to the pressures on floating and submerged bodies and the methods of measuring pressures. Next come chapters on flow in pipes, pressure and friction head and loss from friction, then flow through pipes of varying section and vacuum and siphoning effect. Other chapters take up the effect of change in direction on flow, flow through orifices and flow in open channels, with the methods of measuring and computing such flow. The principles of the Venturi meter, the Pitot tube and the weir are given and the application shown.

As already stated, the book is an introduction to the subject and will be found useful to the student who is beginning the study of hydraulics, also as a reference book on the principles of pressures and flow of liquids.

Mechanics of the Gasoline Engine, by H. A. Huebotter; 312 pages, 153 illustrations, 6 by 9 in., cloth. New York, 1923.

Starting with the fundamental principles of the gasoline engine, the book goes on to engine power and efficiency, the reciprocating parts such as crank and connecting rod, the cylinder and piston, crankshaft, valves and mechanism, flywheel and frame. Following chapters take up lubrication, governing, cooling and inlet and exhaust manifolds.

In the treatment of the analysis of stresses on parts, the practice of copying those of some reliable engine and disregarding stresses imposed by special service is deplored, especially as the analysis is so treated as to be comparatively simple, yet give accurate results. It is emphasized that the most important part of the work of engine design is so to lay out the parts that the engine will be accessible, compact, simple of production and neat in appearance. These are matters that require much practical experience and a knowledge of shop operations and can be treated in a book only in a general way.

The book is intended primarily for the designing engineer, shows the derivation of the equations used which necessitates the use of considerable mathematics but the use of the equations does not involve an understanding of the mathematics by which they are derived.

At the end of each chapter is given a digest of its contents to summarize the important considerations in the design of each part. Also the designer is advised to check his designs by the latest practice to ensure that he is keeping up with the progress of the art.

It is a well thought out book, carefully written and embodying good current practice with the fundamentals which underlie correct design. It will be found a most useful tool by the engineer who is engaged in the design of gasoline engines.

Conveyors Corporation of America in Chicago has issued a circular describing American Air-Tight Furnace Doors.

Wayne Tank and Pump Co. of Ft. Wayne, Ind., have issued an attractively illustrated booklet on the subject of water softening and filtration. The chief aim of this booklet is to give the industrial manager or engineer an insight into the uses and benefits of water softening by the exchange, or Zeolite process. No attempt has been made to cover the subject from a technical standpoint, but it gives a clear and accurate description of the process in general language.

Elliott Co. of Jeannette, Pa., has just issued Catalog X-7, a new publication by the Lagonda Mfg. Co. of Springfield, Ohio. This catalog is devoted to descriptions of Lagonda tube cleaners. It is a 44-page booklet and describes not only cleaners for boiler tubes, but also for economizer tubes, water backs, superheater tubes, large pipes or tubes, condensers, evaporators, etc. A special, high powered cleaner for heavy scale is also described and the use of cleaners in oil refineries is reviewed. Complete lists of repair parts, catalog numbers, etc., are included.

"Modern Engineering for Power Plant Operators" is the title of a 420-page book recently issued by the New York Belting and Packing Co. This book is devoted to a discussion of modern power plant problems from the operator's point of view and is illustrated with numerous line diagrams and halftone cuts. The Section headings will serve to give a general idea of the subjects treated. These are as follows: The Steam Turbine, the Uniflow Engine, Combination Units, High Pressure Boilers, Separators, Condensers, Boiler Feeders, Water Columns and Feed Water Regulators, Feed Water Heaters, Mechanical Draft, Boiler Tests with Forced Draft. Grates for Steam Boiler Furnaces, Stokers, Miscellaneous Appliances, Powdered Coal and other Fuels, Burning Oil to Generate Steam, Oil Engines.